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# **IMPACT OF SCHOOL OUTDOOR ENVIRONMENT UPON PUPILS' PHYSICAL ACTIVITY AND SUN EXPOSURE ACROSS AGES AND SEASONS**

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# IMPACT OF SCHOOL OUTDOOR ENVIRONMENT UPON PUPILS' PHYSICAL ACTIVITY AND SUN EXPOSURE ACROSS AGES AND SEASONS

## THESIS FOR DOCTORAL DEGREE (Ph.D.)

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*“Kalle felt a wild exultation rising in him as he ran on in the darkness. This was life (...) this was real - the tramp of their pursuers' feet behind them, Anders and Eva Lotta's labored breathing, the round cobblestones under his feet, the dusky narrow alleys and temptingly darkish byways and yards where one could hide - all this was splendid. It was going to be an exciting chase. And the best of all was feeling how his body obeyed him perfectly, how quickly his feet moved, and how easily he could breathe. He could easily run like this all night. He felt absolutely supreme, capable of outdistancing a whole pack of bloodhounds, if need be.”*

*Kalle Blomkvist by Astrid Lindgren*

*(with the permission of Saltkråkan AB)*

*To my family Maria, Emelie and Sofia*

# ABSTRACT

**Background and aims:** Among children, the lack of physical activity (PA) is widespread in developed countries. Further, the majority of all skin cancers depend on an overexposure to solar ultraviolet radiation (UVR) in early life. The combination of sufficient PA and suberythral UVR exposure (potentially sufficient for vitamin D production) dispersed over the day is vital to general wellbeing and bone health, especially in growing children and adolescents. However, long regulated school days entail less free mobility and outdoor stay, which may jeopardize the opportunities for cohesive intense physical activity (PA) and suberythral UVR exposure. The impact of the school outdoor environment upon schoolchildren's PA has been studied but not in combination with the exposure to UVR from the sun during the school day in children of different ages during one academic year containing different seasons. The overall aim for this thesis was to examine the cross-sectional impact of outdoor environments at compulsory school level in different seasons upon PA and solar UVR exposure in Swedish pupils.

**Material and Methods:** The impact of school outdoor environment upon pupils' physical activity and UVR exposure during free-mobility, scheduled time and physical education (PE) were studied in 196 pupils aged 7-15 years (grades 2, 5, and 8) at four schools in mid-southern Sweden during 5 consecutive days each in September, March and May. Actigraph GT3X+ Activity monitors were used for PA assessments and for separation of indoor from outdoor stay, supplementary to ocular observation. Predictors for PA during school stay, expressed as mean daily accelerometer counts and time in different PA intensities were measured per season, day, grade and gender. For individual assessment of erythemally effective UVR (joule per exposed m<sup>2</sup> of the skin), a polysulphone film dosimeter badge was pinned to the top of the pupils' right shoulders and worn during school-time during the entire week. Their individual UVR exposures were related to and expressed as fractions of total available ambient UVR in the schools' outdoor environments which differed considering amount of shade, vegetation, and peripheral city-scape quantified as percentage of free sky view calculated by fish-eye photography. Questionnaires and diaries were applied to control for confounders.

**Results:** Overall, free-living PA outdoors generated the highest mean accelerometer counts for moderate and vigorous physical activity (MVPA), and together with outdoor physical education contributed with 50% of total mean accelerometer counts though representing only 25% of the total school time. Season, age, gender and weather had an impact on both PA and UVR exposure, with less PA and UVR exposure. In March, in inclement weather both PA and UVR exposure dropped, especially among older pupils and girls. During all seasons both MVPA counts and UVR exposures were significantly higher among 2<sup>nd</sup> graders vs. 5<sup>th</sup> and 8<sup>th</sup> graders. In September and March play at sport fields had a positive impact on pupils' PA and suberythral sun exposure (potentially sufficient for vitamin D production). Among 2<sup>nd</sup> and 5<sup>th</sup> graders and in September this interaction between attributes of the physical environment and level of PA and UVR exposure was pronounced. In May overexposure to UVR did occur, though green settings with trees and shrubs and fixed play equipment close to the greenery protected from hazardous UV exposure and promoted high levels of MVPA.

**Conclusions:** More time outdoors, at all seasons, would favorably increase school children's chances of reaching recommended levels of PA. There is a potential for prolonged suberythral outdoor stay for play in open areas during fall and early spring at Lat.56°N. Outdoor activities in such settings should therefore be encouraged. In late spring, long outdoor exposures of the youngest pupils warrant UVR-protective outdoor environment. Access to vegetation and/or shaded structures (e.g. trees, bushes, roofs) attractive for play should be provided for.

## SAMMANFATTNING (SUMMARY IN SWEDISH)

**Bakgrund och syfte:** Bristen på fysisk aktivitet bland barn är utbredd i västvärlden. Vidare beror den övervägande delen av all hudcancer på en överexponering för solens ultraviolette strålning (UV) tidigt i livet. Kombinationen av tillräcklig fysisk aktivitet och lagom sol utan fara för brännskada (då även vitamin D kan bildas) spritt över dagen är väsentligt för allmänt välbefinnande och skeletthälsa, speciellt hos växande barn och ungdomar. Men långa, schemalagda skoldagar för med sig mindre fri rörlighet och utevistelse vilket kan äventyra chanserna att få lång, sammanhängande fysisk aktivitet och lagom sol. Hur utemiljön på skolorna inverkar på skolbarns fysiska aktivitet har studerats men inte i kombination med solexponering under skoldagen hos barn i olika åldrar under ett helt läsår som omfattar flera olika årstider. Det övergripande syftet med denna avhandling var att med tvärsnittsstudier över läsåret undersöka den inverkan som utemiljöerna på svensk obligatorisk grundskola har på grundskoleelevers fysiska aktivitet och solexponering under olika årstider.

**Material och metod:** Utemiljöernas inverkan på fysisk aktivitet och solexponering under fri rörlighet under rast, schemalagd tid inklusive skolämnet idrott och hälsa studerades hos 196 elever i åldrarna 7-15 år (2a, 5e och 8e klass) vid fyra olika grundskolor i södra Sverige och mellersta Sverige 5 dagar i rad under september, mars och maj. Actigraph GT3X+ accelerometrar användes för att mäta fysisk aktivitet, och för att skilja på utetid och innetid som ett komplement till okulär observation. Faktorer som kunde påverka fysisk aktivitet under skoltid (uttryckt som genomsnittliga dagliga accelerometer counts, samt olika intensiteter i den fysiska aktiviteten), mättes per årstid, dag, klass och kön. För individuell bedömning av UV-strålning som varje elev utsattes för (joule per exponerad m<sup>2</sup> hud), fästes ytterst på elevernas högra axel en polysulfondosimeter som bars hela veckan under skoltid. Elevernas individuella UV-exponering sattes i relation till all tillgänglig UV-strålning under utetiden och uttrycktes som fraktionen av totala tillgängliga UV-strålningen i skolans utemiljöer. Dessa skiljde sig betydligt åt genom skugga, vegetation, och omgivande stadslandskap och kvantifierades som procent av fri himmel med fiskögonoptik. Enkäter och dagböcker användes för att kontrollera för faktorer som kunde påverka resultaten.

**Resultat:** Överlag genererade fri rörlighet de högsta accelerometer värdena för medel- och högintensiv fysisk aktivitet, och tillsammans med idrott och hälsa undervisningen stod denna för 50% av accelerometer värdena som härrörde från medel- och högintensiv fysisk aktivitet fastän fri rörlighet och idrott och hälsa undervisningen bara stod för 25% av skoltiden. Årstid, ålder, kön och väder påverkade både fysisk aktivitet och solexponering. Under bister väder i mars minskade både fysisk aktivitet och solexponering, speciellt bland flickorna och de äldre eleverna. Under alla årstider låg både fysisk aktivitet och solexponering högre hos elever i andra klass jämfört med eleverna i 5:e och 8:e klass. Under september och mars inverkade lek på idrottsplan positivt på både fysisk aktivitet och solexponering (svag men potentiellt tillräcklig för att bilda vitamin D). Speciellt bland 2:a och 5:e-klassarna och under september fanns en utpräglad sådan interaktion mellan attributen i den fysiska miljön och nivån av fysisk aktivitet och solexponering. I maj förekom överexponering för UV-strålning, fastän grönområden med träd och buskar och lekställningar i grönskans närhet skyddade mot riskabel överexponering för sol och främjade fysisk aktivitet på medel- och högintensiv nivå.

**Konklusioner:** Mer tid ute under alla årstider skulle öka möjligheterna för skolbarn att nå upp till rekommenderade nivåer av fysisk aktivitet. På 56:e breddgraden under höst och vår finns det utrymme för längre utevistelse och för lek under öppen himmel utan risk för överexponering av sol. Uteaktiviteter i sådana miljöer bör därför uppmuntras. Under sensvåren vid långvarig utevistelse bör det finnas tillgång till solskyddande miljöer för de yngsta eleverna i form av vegetation och/eller skuggande konstruktioner (t.ex. träd, buskar, tak) som lockar till lek.

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## LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
BMI	Body Mass Index
CIE	Commission Internationale d'Éclairage/ International Standardizing Committee for the Measurement of Electromagnetic Radiation
CPM	Counts per minute
EWUV	Erythema Weighted Ultra Violet exposure
GEP	Google <sup>TM</sup> Earth Pro
ICNIRP	International Commission on Non-Ionizing Radiation Protection
IU	International Units
LPA	Light Physical Activity
MED	Minimal Erythema Dose
MVPA	Moderate to Vigorous Physical Activity
PA	Physical Activity
PE	Physical Education
SDD	Standard vitamin D Dose
SED	Standard Erythema Dose
SVF	Sky View Factor
TAC	Total accelerometer counts
TLV	Threshold Limit Value
UVR	Ultraviolet Radiation
VA	Accelerometer vertical axis data
VM	Accelerometer vector magnitude data: Calculated from vertical (v), horizontal (h) and transversal (t) axis data by the formula $VM = \sqrt{(v^2 + h^2 + t^2)}$ .

# 1 INTRODUCTION

Physical activity (PA) is an essential lifestyle factor, related to a wide range of health benefits (1). Children's active play and body movement is the engine for physical, emotional and social development (2-4). Unfortunately, studies show that today children are engaged in low levels of daily PA and it seems to be a decline in PA and an increase in sedentary behavior over time in high-income countries (5), a situation that likely lead to an increase in chronic diseases in the future, such as diabetes, osteoporosis, obesity, depression and certain cancers (6). Further, some studies reveal that activity patterns established in childhood tend to follow up in adolescents and into adulthood (7, 8).

School day's scheduled physical education, opportunities for free play and movement as well as school environment design both inside and outside is associated with children's physical activity during school hours (9). Several studies show that outdoor stay time is the most important factor to increase time spent in moderate to vigorous physical activity (MVPA) (10, 11). However, there is no consensus about why or how outdoor stay time triggers this increased amount of physical activity.

In order to be healthy and safe during outdoor stay time, the design of the environment should protect the children from physical damage, noise and against local factors like air contamination. Another factor – we could call it a global factor that is vital for health is UV radiation (UVR) from the sun. Children need UVB radiation from the sun for vitamin D formation, but they must be protected against hazardous UVR and, above all, against burns (12, 13). The purpose is that children are extra sensitive to the sun's UV rays while spending a lot of time outdoors with play and other recreational activities. In Sweden the incidence of skin cancer increases rapidly in both men and women, and the main causes are sunburns early in life and the accumulated amount of UV exposure throughout lifetime (14, 15).

Measurements show that pre-school children who have access to vegetation and exciting playgrounds in the shade are exposed to low UV radiation, even though they are staying a lot of time outdoors (16). However, we do not know today how these relationships look like in school-age children.

This thesis will contribute additional pieces to how outdoor environment in Swedish elementary schools affects physical activity and UVR exposure in schoolchildren of different ages and in different seasons.

## **1.1 PHYSICAL ACTIVITY**

### **1.1.1 Physical activity – definitions and related concepts**

PA is commonly defined as any bodily movements resulting from skeletal muscle contraction that leads to an increased metabolic rate over resting energy expenditure (17). For children and adolescents this broad concept includes play, games, transportation, chores, recreation, physical education, or exercise and sports. Exercise and sports refer to a more structured and intense form of PA, intended to increase or maintain physical fitness including cardio-respiratory fitness, muscle strength, body composition, and other attributes that relate to the ability to perform sustained PA (17, 18).

### **1.1.2 Bodily response and adaptation to physical activity**

The bodily response and adaptation to PA depends on type and frequency of activity, bouts during a given time period (duration) and intensity of each bout (19). Energy metabolism increases linearly to PA intensity and may be divided into three different intensity levels with their respective metabolic equivalent (MET), light PA (LPA) (< 3 METs), moderate PA (MPA) (3-6 METs), and vigorous PA (VPA) (> 6 METs), where 1 MET considers a resting metabolic rate of  $1 \text{ kcal} \cdot \text{kg}^{-1} \cdot \text{h}^{-1}$  or  $3.5 \text{ ml O}_2 \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$  in adults obtained during quiet sitting (20). In children and adolescents the resting metabolic rate ( $1.71 \text{ kcal} \cdot \text{kg}^{-1} \cdot \text{h}^{-1}$ ,  $5.92 \text{ ml O}_2 \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ ) and working metabolic rate is different from that in adults, likely due to different body structure and body composition (21). Regular and sustained PA, especially intense PA, throughout childhood and adolescence increases the capacity of the cardio-respiratory system (i.e. increased maximal oxygen uptake) and skeletal-muscle system (i.e. increased muscle strength, coordination, mobility and motor skills) (22).

### **1.1.3 Assessment of children's physical activity**

Children's activity pattern is usually sporadic and intermittent, with frequent and short bouts which makes it difficult to assess their PA in relationship to health outcomes with respect to frequencies (regularity), intensity (level of activity), duration (activity time), and type of activity performed (i.e. walking, running, climbing etc.) (23). Subjective methods (i.e. questionnaires, interviews, self-reports) and objective measurement (i.e. direct observation, heart rate monitors, and motion sensors) may be applied in measuring PA. The choice of a suitable instrument depends on the specific research question as well as the relative importance of validity and utility (24). Applying a mix of both subjective and objective methods may be preferred when studying children's complex PA patterns. Subjective measurement will amongst others tell you about the type of PA that is carried out, and the way children have experienced it, whereas objective measurement in the best of cases give a detailed picture of duration, intensity and frequency of PA (25). Due to age-related variances, mainly in the ability of abstract thinking and detailed recall children are less likely to achieve

accurate self-report assessment than adults are (26). In the present studies subjective (questionnaires and diaries) and objective (direct observation, accelerometers) assessments were used.

Accelerometers detect time-stamped body-accelerations in different directions and register data in counts several times per second, which enables information regarding motion intensity, duration and frequency. Accelerometers have been calibrated for children against heart rate (27), indirect calorimetry (28) and metabolism by doubly labeled water (29) and are reported to be reliable and valid when measuring children's free-living PA (23).

Accelerometer counts are sums of post-filtered body-accelerations at a specific measure frequency (Hertz value) of the accelerometer, and cannot be translated between different brands of devices placed in different positions of the body (30). All body-acceleration data without the filter may be used as raw-data, which has the advantage of including all PA behavior in the analysis, but this requires more complicated and time consuming analysis (31). The outcome from accelerometer measured PA during a given measurement period is total accelerometer counts (TAC). The commonly used mean PA intensity in counts per minutes (CPM), may be calculated by dividing accelerometer counts with measured time (minutes). Threshold limits (cut points) for CPM representing different PA intensity levels (e.g. LPA, MPA, VPA) are useful when assessing the proportion of children reaching recommended levels of PA, but comparable results require the use of the same cut points (31). The sampling interval (epoch time), is a fixed number of seconds (1-60 seconds) in which the counts are summarized. In young people (from preschoolers to adolescents), shorter epochs (1–15 s) are recommended to capture short bouts of activity occurring frequently in these age groups (32, 33). Children's and adolescents' total amount of time spent in MVPA has been shown to increase with shorter epoch times (34, 35).

Modern multi-axial accelerometers capture body acceleration in vertical- horizontal- and transversal axis directions and register time-stamped data of intensity in each activity axis. Compared to older uniaxial accelerometers these modern accelerometers more adequately reflect non-ambulatory activities with accelerations other than vertical. This is of significance when it comes to assessing the quality of PA and thereby the pattern of activity (36).

However, in children's PA the vertical axis dominates during ambulatory activities, and a review, examining validity of multi-axial compared to uniaxial accelerometers, revealed that free-living PA results from different accelerometers are comparable (37).

#### **1.1.4 Children's physical activity and health**

Physical activity, not least of running, romping, climbing and scampering, contributes to verbal, emotional and social development (2). PA is further a mighty contributor to consolidating active lifestyles in childhood and puberty, with positive impact on weight control, glucose tolerance, blood pressure, bone mineralization, functioning of the immune system, mental health and hence reduced risk of common diseases in adulthood (1, 38, 39).

Long, regulated school days however may jeopardize the opportunities for cohesive intense PA, especially outdoors, thereby increasing the risk of obesity, asthma, attention deficit / hyperactivity disorder (ADHD), myopia and vitamin D deficiency, conditions that increasingly manifest themselves before puberty (40-42).

Consensus guidelines urge children and adolescents to perform  $\geq 60$  minutes of moderate to vigorous PA (MVPA) on most days of the week to promote health benefits to be sustained into adulthood (1, 43-45). Depending on the accelerometer cut-off point applied to define MVPA, at best about 87% applying the most common cut off points i.e.  $>2000$  counts/minute (CPM), and at worst, no more than about 3% of children and adolescents are reported to reach this level (46).

There are studies showing the importance of school induced PA to maintain healthy PA levels (47-49). Further, school day segments such as scheduled recess and physical education (PE) have been identified as an area to endorse pupils' MVPA (11, 50, 51). The World Health Organization (WHO) recommends that PE should be considered as an integrated part of creating health-promoting environments (52).

### **1.1.5 Outdoor environment encouraging physical activity**

Previous studies on Swedish and American preschool children have shown that the outdoor environment in terms of surface (vast, multileveled), and access to playable vegetation impacts children's health in terms of leaner body, longer night sleep, increased well-being, improved physical activity combined with suberythemal sun exposure (53-55).

The impact of children's environment at compulsory school is still largely unexplored. Compared to preschool however, the transition to regulated school days frequently entails restricted opportunities for free mobility in the outdoors. Older pupils have been shown to spend less time outdoors which has implications both for the role of outdoor environment and pupils' health (56) and in cross-sectional studies PA levels are observed to decline by age (57, 58). For the sake of daily PA and its health benefit, it is therefore important to design guidelines for healthy school environments that trigger PA (11, 59). Variables at both individual and school level affect children's PA (60, 61). However, the differences in children's PA, their individual characteristics and hence what school environment they prefer need to be better understood. Especially gender differences deserve special attention as it is obvious that boys in almost all grades are more physically active than girls during school recess (57, 62, 63).

The actual role of the outdoor environment may be a relevant predictor of PA, but the evidence is conflicting or unclear (11, 61, 62, 64-66). While some PA tends to be carried out regardless of place there are so called "place-activities", such as schoolyard play which tends to be intimately dependent on specific place attributes (67). In this context, the concept of "play setting" may be relevant. The terminology aligns with the tradition of ecological



psychology (68) using “behavior settings” to denote how configurations in the physical environment become associated with distinct patterns of human behavior evolving at a site over time.

School children’s PA has been shown to be associated with the duration of outdoor stay and some environmental factors like playground area, play space ( $\text{m}^2/\text{child}$ ) and equipment availability (69-72). Interventions based on playground markings and physical structures showed an increase in schoolchildren’s PA during recess (73). Further, there is evidence that designed outdoor surfaces at primary school attract and thereby increase pupils’ PA during recess and outdoor playtime (71, 72, 74). Also the important role of paved open spaces for PA is pointed out as children tend to run a lot in many of the traditional schoolyard games including elements of hide and seek and chasing (74).

## **1.2 SUN EXPOSURE**

### **1.2.1 Solar ultraviolet radiation**

Ultraviolet radiation (UVR) is part of the spectrum of electromagnetic radiation produced by the sun. It is divided into three bands of different wavelengths, UVA 400-315 nm, UVB 315-280 nm and UVC 280-100 nm. UVC is absorbed by atmospheric ozone and is hence irrelevant considering human health. UVA passes through the atmosphere with little change, whereas about 10% of the extraterrestrial UVB reaches the earth’s surface, but varies widely depending on latitude and time of day (75). UVA penetrates the human skin more deeply than UVB. Action spectra for biological responses indicate that both UVA and UVB are absorbed by DNA (76). Consequently damage to DNA appears to be a key factor in the initiation of the carcinogenic process in the skin (77). UVB radiation is crucial for the formation of vitamin D and interacts with a protein called 7-DHC (de-hydro-cholesterol) in the skin, which converts it into vitamin D<sub>3</sub>, the active form of vitamin D (78).

### **1.2.2 Consequences of UVR exposure**

Overexposure to solar UVR, especially UVB, leads to obvious mutagenic changes which may cause negative health effects related to the skin such as erythema, skin aging, carcinogenesis (nonmelanoma skin cancer, NMSC and cutaneous malignant melanoma, CMM) (79). Nonmelanoma skin cancer is the most common cancer and CMM the most rapidly increasing cancer among both adult women and men in Sweden with an annually increasing incidence rate for malignant melanoma of 5.7 percent for women and 5.9 percent for men in 2013 (15).

The consequence of solar radiation on human health depends on the intensity and duration of erythemally effective solar radiation and the surface area of exposed skin. The solar

UVR-intensity depends on several atmospheric conditions especially the angle at which the sun's rays pass through the atmosphere. Between the tropics, solar UVR penetrates the atmosphere at a more or less perpendicular to the ground surface and hence a higher proportion of shortwave UVB reaches the ground, compared to higher latitudes with lower solar elevation angles at which the radiation travels longer through the atmosphere (80). Season, time of day, altitude, ground reflection and the presence of clouds, dust, and various organic compounds can also change the intensity of incident solar radiation (81).

Normally, peoples' UVR exposure from the sun is 5-15% of the global ambient UVR and seems similar between different age groups and genders, although among youngsters boys are more exposed than girls (77). The strongest exposure-disease relationship is the difference in skin type and erythema UVR exposure. The Fitzpatrick scale with six by sensitivity descending skin types (skin type I – VI) is the commonly used classification of skin type for UVR sensitivity (77, 82). Skin types I - III are most common in temperate zones, which include the Southern and middle parts of Sweden.

### **1.2.3 Threshold limits for potential vitamin D formation and suberythema UVR exposure**

Examples of health reasons for outdoor stay are bone growth. Outdoor stay also counteracts sedentariness and obesity in schoolchildren. In this context, vitamin D is not infrequently mentioned. It has been shown that there is a significant combined impact of PA and vitamin D levels during childhood and adolescence upon the peak bone mass in early adulthood, which affects bone health throughout life (83).

Whether the pupils' measured erythema exposures are too high and possibly detrimental, or insufficient from health perspectives related to vitamin D is debatable with regard to vitamin D acquisition and especially the action spectrum for vitamin D (84, 85). To put exposures into a context these perspectives therefore discussed in relation to defined UVR guidelines, limits or recommendations i.e. erythema, actinic and vitamin D-effective. Exposure to UVR may therefore be assessed and compared along: 1) the Standard Erythema Dose (SED) (86), 2) the Threshold Limit Value (TLV) according to the guidelines by the ICNIRP's UV-hazard evaluation action spectrum to avoid acute effects from artificial UVR (87) and 3) an effective exposure suggested for adequate vitamin-D formation (SDD), derived from model calculations (88).

- 1) For erythema UVR a "Standard Erythema Dose" (SED) has been defined as  $100 \text{ J/m}^2$  UVR spectrally weighted with CIE's erythema reference action spectrum (86) – but it has little to do with "erythema" or the concept "Minimal Erythema Dose" (MED) that depends on individual sensitivity and skin type. Roughly, 2 SED are required to induce slight erythema (1 MED) in individuals with sun sensitive skin (skin type I).

- 2) For hazard evaluation of UVR there is an internationally agreed threshold limit value (TLV) intended to avoid acute effects mainly in the eye (e.g. photokeratitis) from artificial UVR during one day at workplaces (87). Originally based on an envelope curve around several TLV effects and studies, the hazard evaluation action spectrum is also applicable for the skin (erythema) with a safety margin (89). That action spectrum, however, is different from the CIE erythema reference action spectrum (Fig. 1), and ICNIRP's TLV ( $30 \text{ J/m}^2$ ) is different from CIE's "SED" ( $100 \text{ J/m}^2$ ). The ICNIRP UV-guidelines and -limitations are legally binding in all EU-countries to limit personal UV-exposures from artificial UV-sources in a working environment (90). In the present studies they have been applied to natural solar UV. Schoolyards, school surroundings, and outdoor premises are parts of school children's compulsory working environment during a school day. To enable comparison of the pupils' measured erythema exposures along the ICNIRP TLV they have been transformed for a range of known solar UV-spectra to CIE-erythema exposures.

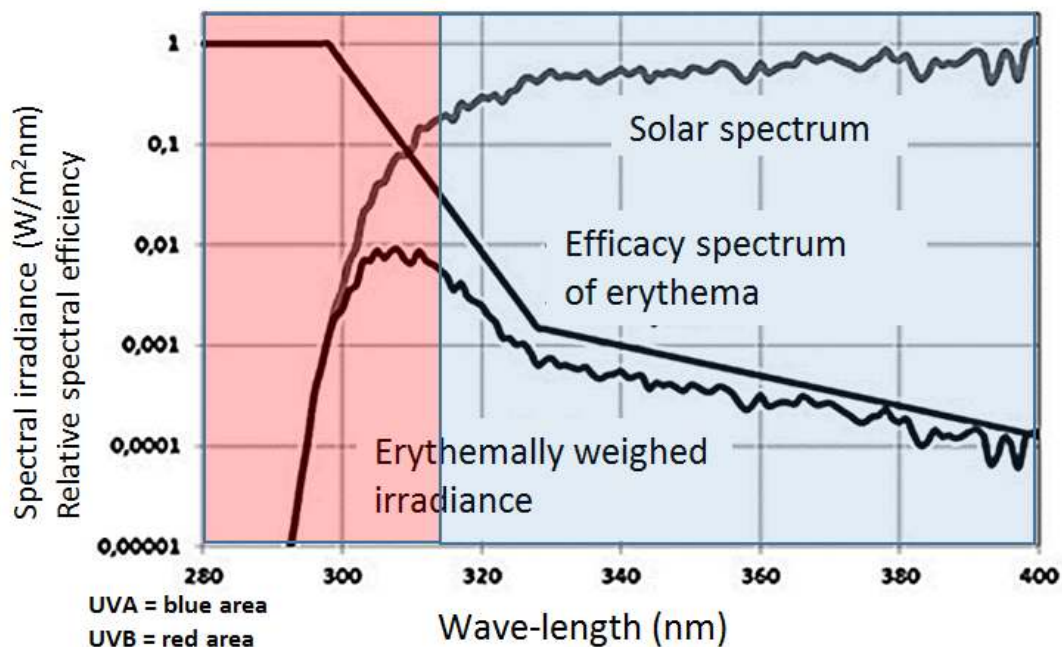


Figure 1. Shows the sun's UV spectral strength with respect to the sensitivity of the skin for erythema (redness), i.e., "erythemally weighed irradiance" (91).

- 3) For the formation of vitamin D exposure to UVR (Standard vitamin D Dose, SDD), equal to  $\frac{1}{4}$  of a minimal erythemal dose every other day on  $\frac{1}{4}$  of the total skin area of sun sensitive persons (skin type I) has been suggested to provide health benefits. It has been estimated to be equivalent to solar exposure of hands, arms and face 15-25 minutes at noon at mid-latitude in March and to equal an oral dose of about 1000 I.U. (13, 88). This interpretation is applied for comparative purposes in this study as  $\frac{1}{8}$  MED on  $\frac{1}{4}$  skin area each day, or 500 I.U. vitamin-D daily. The American Academy of Dermatology (AAD) recommends that sufficient vitamin D should be obtained through food and

beverage and to follow the guidelines of the Institute of Medicine (IOM) with an intake of 600 IU daily (92). In Sweden daily recommended vitamin-D intake has hitherto been 400 IU (93).

Although there may be no “safe” UV dose considering skin cancer risk, the above criteria serve to put exposures measured in this study into a perspective.

#### **1.2.4 Impact of environmental factors upon UVR exposure**

Solar UV radiation at ground level may vary considerably due to several variables, such as the solar zenith angle, which depends on latitude, season and time of day. It also depends on the atmospheric conditions like stratospheric ozone, aerosols, cloudiness and other weather parameters. UV exposure also increases at higher altitude (77, 94).

A study from Texas showed that an artificial shade sail in a playground effectively filtered out 91% of UVR from the sun, and reduced the exposure (number of SEDs) by 60% in some elementary school children (95). The shade sail significantly reduced the incoming solar UVB radiation as a function of its size, orientation, color, transmissivity, and sky coverage, all elements that are critical to incorporate into the design of any urban area to obscure both the sun and sky (95). Similar reductions in UVB were observed in measurements of UVR in the shade provided by trees at various sun angles at pedestrian level (96). The same study showed, that by allowing children to make use of the limited shade in the schoolyard, it would reduce their exposure (number of MEDs) sufficiently to eliminate the risk of sunburn (96).

Environmental modification would thus enable long-term positive impact on sun exposure. It has been shown that green outdoor environment protects from excessive UVR due to a substantial cut in UV exposure during free play (53, 54). Outdoor environment with low-reflecting greenery reduces exposure to UVR (97) and additionally promotes sun protective behavior as part of a play behavior typical of outdoor settings in which children tend to move in between different places surrounded by vegetation (98). Reflectance of UVR from gravel surfaces, not uncommon on school grounds, may be up to 25% compared to grass with almost no reflectance of UVR (99). Outdoor sporting activities have been associated with high UVR exposure, often due to the free sky view on ball play areas, ensuing risk of sunburn (100). Yet, other studies show that outdoor activities, particularly soccer and gardening, during childhood could even lower the risk of developing melanoma (101).

Sun exposure (UVB) contributes to keeping up vitamin D levels and thereby has health effects, especially for growing schoolchildren confined to mandatory indoor stay during school time. They may therefore miss out on suberythemal sun exposure with the potential to form vitamin D which in theory would be possible from late March at mid-latitudes (mid-

southern Sweden included) as the UV index approaches 2 (Figure 2). From late April until the end of spring term in early June the risk of sunburn is obvious.

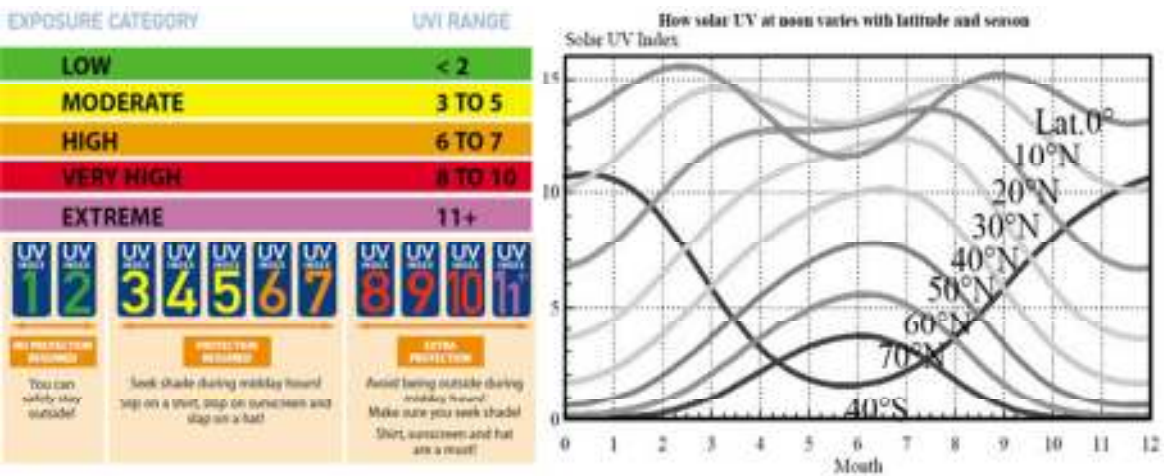


Figure 2. Left: WHO’s solar UV-index exposure categories ranges and protection requirements (102). Right: Latitudinal and seasonal variation of the solar UV-index at noon for cloud-free sky and climatically normal stratosphere ozone layer (103).

## 2 AIM AND SPECIFIC OBJECTIVES OF STUDY

The overall aim of this thesis was to explore the impact of school outdoor environment upon Swedish pupils' health in terms of health enhancing PA and sun exposure across different ages (7-15 years) and seasons (September, March and May).

Specific objectives:

- To explore the impact of indoor and outdoor free-living PA and scheduled physical education upon intensities of PA.
- To analyze the impact of school outdoor environment in terms of playground features, space, topography and vegetation upon the patterns of moderate to vigorous physical activity (MVPA).
- To analyze erythematous UVR exposure in outdoor environments differing in surface, amount of vegetation free sky view, and to relate the results to defined limits for UVR exposure, given the recommendations for increased outdoor stay at school.
- To investigate the impact of different types of play settings upon physical activity and UVR exposure, and to relate the results to recommended levels of PA and defined limits for UVR exposure, given the recommendations for increased outdoor stay at school.

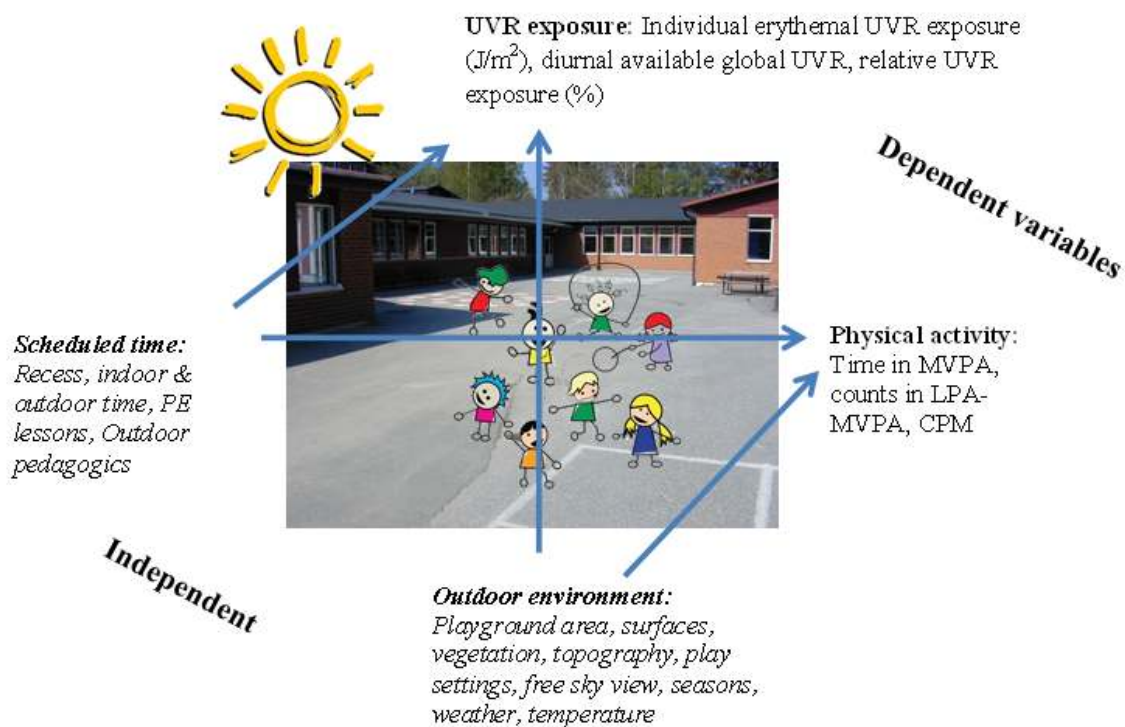


Figure 3. The interaction (arrows) between independent (scheduled time and outdoor environment) and dependent variables (UVR exposure and Physical activity).

### 3 METHODS

Aims, participants, independent and dependent variables and measures for the different studies of Swedish pupils during stay at the school premises are presented in table 1.

Table 1. Overview of the studies. Sweden 2012-2013.

STUDY	I	II	III	IV
<b>Participants</b>	179 pupils, 92 boys, 87 girls 72 2 <sup>nd</sup> graders, 81 5 <sup>th</sup> graders, 25 8 <sup>th</sup> graders	189 pupils, 101 boys, 88 girls 75 2 <sup>nd</sup> graders, 88 5 <sup>th</sup> graders, 26 8 <sup>th</sup> graders	172 pupils, 91 boys, 81 girls 70 2 <sup>nd</sup> graders, 80 5 <sup>th</sup> graders, 22 8 <sup>th</sup> graders	140 pupils, 70 boys, 70 girls 60 2 <sup>nd</sup> graders, 80 5 <sup>th</sup> graders
<b>Independent variables</b>	Time spent indoors and outdoors, weekdays, weather, temperature, seasons, grades and gender	Outdoor time, school environment, seasons, grades and gender	School environment, outdoor time, sky view fraction, seasons, and grades	School environments, play settings, outdoor time, sky view fraction, seasons, grades, and gender
<b>Dependent variables</b>	Accelerometer counts in MVPA indoors and outdoors  <i>MVPA based on Vertical axis – accelerometer data</i>	Accelerometer determined minutes in MVPA outdoors and percentage in MVPA outdoors  <i>MVPA based on Vector magnitude – accelerometer data</i>	UVR exposure (J/m <sup>2</sup> ), relative UVR exposure (% of available UVR), and SVF as a proxy for UVR exposure	Accelerometer counts in MVPA outdoors, UVR exposure (J/m <sup>2</sup> )  <i>MVPA based on Vertical axis – accelerometer data</i>
<b>Measures</b>	Mean values, Standard deviations	Mean values, Standard deviations	Mean, Median, Standard deviations, 5-, 25-, 75-, 95-percentile and maximum values (boxplot)	Mean values, Standard deviations, percentage distribution (pie chart), 5-, 25-, 75-, 95- percentile and maximum values (boxplots)

#### 3.1 SELECTION OF SCHOOLS

The schools were selected reflecting the variation of elements that are commonly present in Swedish schoolyards, considering differences in the overall layout of the outdoor environment. Particularly the total size of the schoolyard, its topography, surfaces with woodland, trees and bushes, and the presence of ball play areas, play equipment, and also scheduled outdoor education were taken into consideration. A prerequisite for selection was that pupils of all ages had access to the same schoolyard. Further, attempts were made at selecting the schools to reflect the socio-economic composition of the municipalities of the whole country, with a majority of the population living in medium-sized cities outside or on

the outskirts of a metropolitan area (104). For socioeconomic classification the ISCO code was applied (European socio-economic classification, ISCO, 1988). The schools were attended by 400 - 500 1-9<sup>th</sup> graders, and located in cities with similar socio-economy (Table 2).

Table 2. The socio-economic composition of the municipalities in which the selected schools are situated\*.

<b>Municipality</b>	<b>Tierp</b>	<b>Nynäshamn</b>	<b>Kalmar</b>	<b>Swedish mean</b>
Population	20744	27752	66571	<b>34466</b>
Unemployed (%)	5,9	6,4	5,8	<b>6,9</b>
Employed (%)	68,8	71,3	65,7	<b>67,1</b>
Income (tkr), mean	238,6	269,4	253,0	<b>270,2</b>

\* According to Statistics for the School year 2012/2013 the proportion (%) of pupils having parents with higher education was 34 for school 1, 33 for school 2, 67 for school 3, and 70 for school 4 whereas the Swedish mean was 50.

Schools no. 1 and 2 were located in smaller municipalities with 20744 and 27752 residents respectively in eastern middle Sweden, both with woodland adjacent to the schoolyard. Schools no. 3 and 4 were located in a medium-sized town with 66571 residents in southeast Sweden, the former bordering on the inner-city streetscape and the latter on the outskirts of town next to a block of flats.

The schoolyard of School no.1 (“Art Grass 1” in study I-III) was flat and dominated by ball courts with art grass and with surrounding woodland at some distance. Large paved areas surrounded the buildings and there was some fixed play equipment like swings, slides and climbing frames surrounded with graveled surfaces. School no. 2 (named “Forest 2” in study I-III) had paved areas around the building with a vast graveled ball court to the south side of the building and a larger woodland area in its immediate surrounding with some fixed play equipment like swings and climbing frames and a small hill surrounded by trees. The schoolyard of school no. 3 (named “City 3” in study I-III) was surrounded by a stone wall and dominated by paved surfaces containing ball courts of gravel, benches and manicured vegetation. The area of school no. 4 (named “Hill 4” in study I-III) with play equipment by the buildings sloped down from there and flattened into a plain towards the fence that surrounded the area. A large grassy sport field was located in the south and a small area with shrubs and trees between the school building and the sport field.

### **3.2 STUDY DESIGN AND PARTICIPANTS**

A repeated measurement study design was applied and data collected during five consecutive school days on three occasions during the same academic year, fall (September 2012), late winter (March 2013) and late spring (May 2013).

The study sample was drawn from 259 available 2<sup>nd</sup> graders (7-8 years), 5<sup>th</sup> graders (10-11 years) and 8<sup>th</sup> graders (13-14) at four municipal schools. The school management, the pupils, teachers and parents received detailed information on what the study would imply for the



pupils. After obtaining permission, the parents and their participating children signed a written consent form. A sample of 196 (76%) agreed to participate (Figure 4).

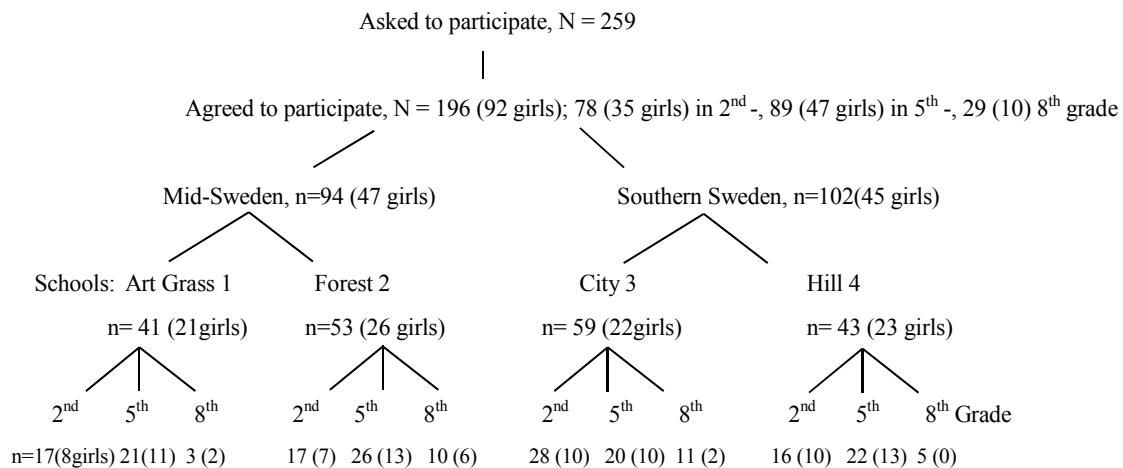


Figure 4. The overall distribution of included participants of different schools, grades and gender. Sweden 2012.

The pupils answered (2<sup>nd</sup> graders did so together with their parents) a questionnaire regarding after-school PA and family. Further, the pupils filled out a diary each day to answer questions regarding potential confounders (medication, feeling well/ unwell, after-school PA).

### 3.3 FIELDWORK

Fieldwork was carried out during 9 weeks, with three weeks each in September 2012, March 2013 and May 2013, and one week in each of the three locations, starting in the North and proceeding to the South in September, and going in the reverse order in March and May to control for differences in the solar zenith angle (Fig. 5)

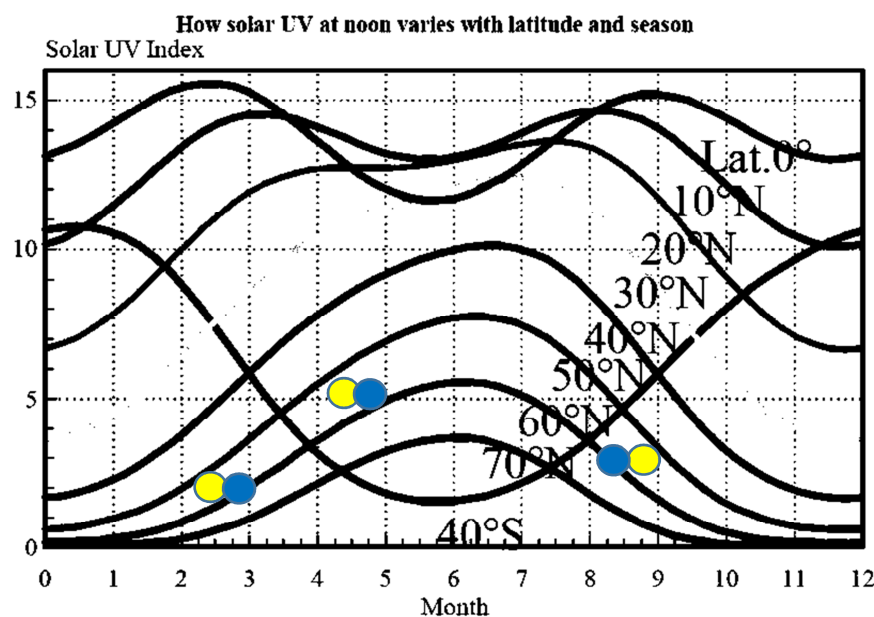


Figure 5. The fieldwork during September 2012, March 2013 and May 2013 at the studied schools positioned in the season and latitude UV-index diagram of figure 2. Schools no.1 and no. 2 (blue dots), schools no.3 and no.4 (yellow dots).

### **3.3.1 Anthropometry**

Height, weight and waist measures were performed in 2<sup>nd</sup> and 5<sup>th</sup> graders during all seasons and in 8<sup>th</sup> graders in March. We used a standard clinical procedure with a digital scale for weight (Beurer GS 27 Happystripes, CE Utrecht), a transportable stadiometer for height (Seca 217, UK Birmingham) and a measuring tape for waist measure.

### **3.3.2 Observations**

The number of pupils in each observed class was in mean 16 pupils/ class (range 5 – 28). The inexperienced observers were carefully instructed, both by the observers with experience of schoolyard observations and by the researchers themselves. Each observer was assigned his/her respective class throughout the school year and during the course of the weeks the observers became familiar with the class assigned to them, which made it easy to learn the pupils' names, and thereby simplified the observations during recess. Each observer had a protocol with the pupils' names and time stamped their arrivals and departures from the school premises, as well as their in- and outdoor times, in addition they disposed of a map of the schoolyard in A3 format to mark the pupils' positions during outdoor stay.

## **3.4 SEPARATING INDOOR AND OUTDOOR PA (STUDY I)**

Each child was categorized as indoors when observed entering the school building. Outdoor activity was categorized from the moment the child stepped outside onto the schoolyard area. Each time the child changed between in- and outdoor stay, the observer noted the exact time of transition for each child separately, but the time each child spent in different parts of the schoolyard was not recorded.

Apart from measuring time-stamped duration, intensity and frequency of PA the accelerometers (Actigraph GT3X+ Activity monitors, US Pensacola) enable location of activity in terms of indoor or outdoor activity (supplementary to ocular observation), due to built-in light sensors (Actilux). The children were told to wear the monitors outside their clothing to get valid lux-values.

The cutoff point of lux-value separating indoor from outdoor differs widely depending on time of day, latitude, season, weather and environment due to differences in solar angles and shadowing environment. The recommended cutoff point of 240 lux presented by Flynn et al. 2014 is valid for Tennessee Knoxville at latitude 35° N (Flynn et al., 2014). However, this can't be expected to be valid for at 56-60° N, i.e. the positions of the schools under study (105). Ambient light data was sampled and stored at a 1 Hz rate. When a downloaded data file is converted into an accumulated “.agd” format with epochs longer than one second, the lux values for that epoch were averaged (GT3X+ Device Manual 2012). The lux readings,

when matched with ocular in-and outdoor observations indicated the adequate cut-off point at 130 lux to discriminate between in- and outdoor stay at our selected schools (Table 6). Indoor lux-data was analyzed from the accelerometers when all children were in the classroom in the morning before AM recess, and before/after lunch break, and outdoor data was selected from AM recess, lunch break and PM recess, see Table 3.

Table 3. Accelerometer measured lux values indoors and outdoors in 2nd grade pupils at school no.1

School no.1 in 2nd grade (n=10)	OUTDOOR (Lux)				INDOOR (Lux)			
	Time	Mean	SD	MIN	Time	mean	SD	MAX
SEPTEMBER	09.10-20	1549	751	159	8.30-40	23	32	120
	11.20-40	1891	641	<b>136</b>	10.10-20	32	39	125
	13.30-40	1814	740	210	12.00-10	7	19	124
MARCH	09.10-20	2015	590	250	8.30-40	10	21	118
	11.20-40	2324	360	328	10.10-20	21	26	106
	13.30-40	2290	380	271	12.00-10	18	26	110
MAY	09.10-20	1729	590	209	8.30-40	15	22	110
	11.20-40	1732	572	157	10.10-20	5	17	78
	13.30-40	2135	546	180	12.00-10	21	34	<b>130</b>

### 3.5 SCHOOLYARD AREA (STUDY II)

An estimate was provided of the total schoolyard areas (m<sup>2</sup>), ball areas (soccer fields, basket fields, markings e.g.), green areas (woodland, grass, trees and bushes) and areas varying in use depending on season (used play area). The Google™ Earth Pro (GEP) software using aerial pictures of the playgrounds and the polygon measurement tool, described by Ridgers et al. 2010, were applied at each one of the four schools (71). Topography (sum of hills and slopes), vegetation (amount of trees, bushes and grass), fixed play equipment (swings, slides, climbing frames) and playground markings were inspected and counted by ocular inspection.

The computed amount of space, used by the pupils during the various seasons was based on the maps on which all the used positions during recess were marked (Table 4). The percentage of used play space was obtained by dividing used play space by available schoolyard area. To calculate the variations between school, grade and seasons of the average play space (m<sup>2</sup>) used per child, the measured used play spaces were divided by the number of pupils in each grade.

Table 4. School outdoor environmental areas. Swedish schools, 2012-2013,

Outdoor environment	School no. 1 "Art Grass 1"	School no. 2 "Forest 2"	School no. 3 "City 3"	School no. 4 "Hill 4"
Location (Latitude)	60.3°N	59,0°N	56.4°N	56.4°N
STUDY II				
School outdoor area (m2)	24890	23482	13273	26613
Outer limit of surface used for play (m2) 2nd grade	13915	9068	6562	12942
Outer limit of surface used for play (m2) 5th grade	16592	12358	10111	12942
Ball play area (m2)	5850	2800	2290	3075
Green area (m2)	1720	7500	2200	2700

**3.6 FREE SKY VIEW FACTORS (STUDIES III)**

One researcher at each grade noted the pupils’ positions and type of activity they were involved in during each recess and outdoor stay resulting in maps illustrating the most dominating areas of the schoolyard per category of pupils related to school, season and gender. From those positions the fraction (%) of visible free sky (Sky View Fraction – SVF%) was determined by fish eye photography of the sky one meter above the ground with the same pole position (North = upper photo position) (106).

The mean fraction of free sky for all position views per site, season and grade was then calculated. The mean percentage of free sky view was 82% at school no. 1 (Art Grass 1), 62% at school no. 2 (Forest 2), 76% at school no. 3 (City 3) and 77% at school no. 4 (Hill 4). Figure 6 displays images (sky view photos and landscape photos) of one representative setting from each school.



Figure 6. Images of one representative setting from each school; (a) school no.1 “Art Grass 1”, (b) school no. 2 “Forest 2”, (c) school no. 3 “City 3” and school no.4 “Hill 4”.

**3.7 PLAY SETTING (STUDY IV)**

In the delineation of categories for further analysis the way pupils play activities were distributed across the outdoor environment was considered. The delineation resulted in four distinct types of “play settings” each containing a characteristic pattern in pupils activities, which could be related to attributes of the physical environment. The four dominating play settings more or less accessible to pupils at each of the four schools were; 1) Fixed play equipment, 2) Paved surfaces, 3) Sport fields and 4) Green settings. The number of settings in each category and at each school were counted and illustrated in table 5.

Table 5. The amount of different play settings at each school

Outdoor environment	School no. 1	School no. 2	School no. 3	School no. 4
Play setting 1: Fixed play equipment areas (number of settings)	6	10	9	5
Play setting 2: Paved surface areas (number of settings)	11	11	11	11
Play setting 3: Sport fields (number of settings)	6	3	2	3
Play setting 4: Green settings (number settings)	5	7	5	4

Figure 7 displays photos of the four delineated play settings at school no. 1 in 2<sup>nd</sup> grade pupils and sky view photos taken in the middle of the play setting.

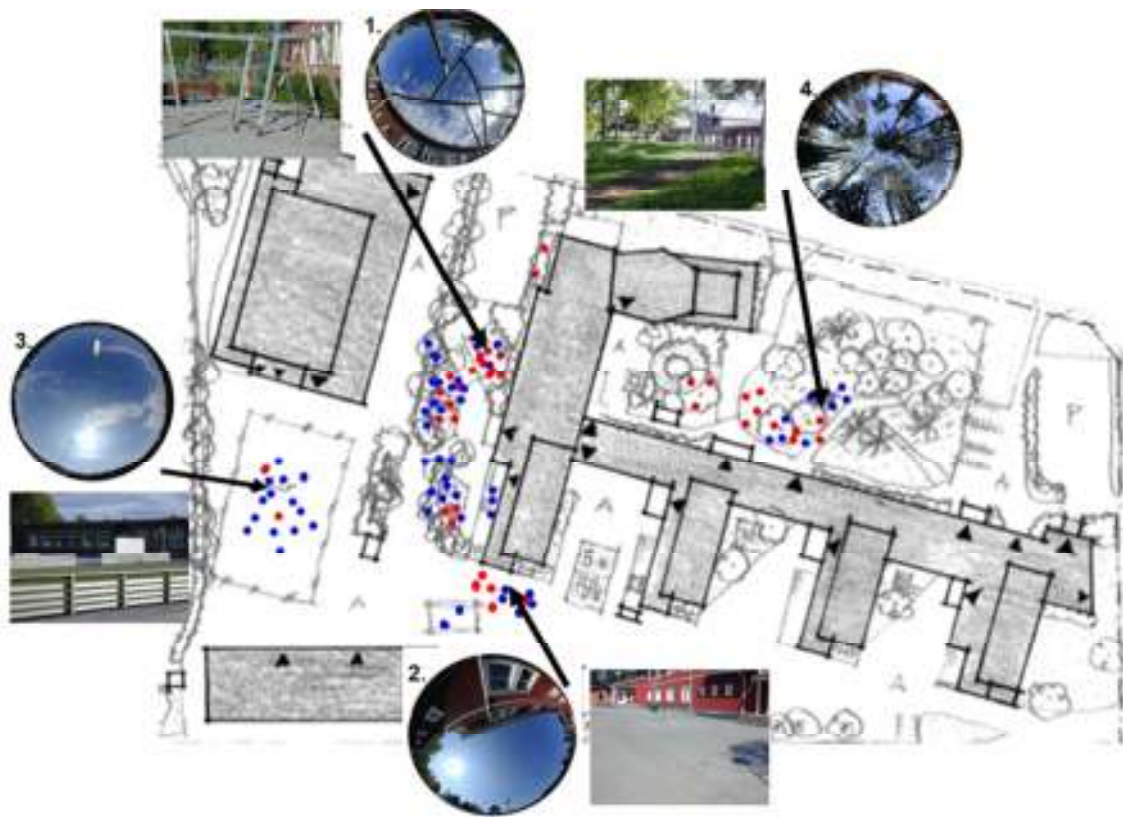


Figure 7. Example of play settings and sky view photos at school no.1; 1-fixed play equipment, 2- paved surfaces, 3- sport fields, 4- green settings. Pupils are marked with blue (boys) and red (girls) dots on the map.

### 3.8 ASSESSMENT OF PA

As mentioned above accelerometers were used for the assessments of PA. The observer mounted the accelerometers in the right position in the morning when the children arrived at school and took them off when leaving school. The children were told to wear the monitors over their right hip, and were instructed to carry out their normal activities.

Four days of monitoring is a proven sufficient length of time to determine habitual whole day PA levels in children (107, 108). As whole day measurement of PA was not the object, only PA at school was measured. Inclusion criteria were based on the reasoning that the scheduled time during a school week is crucial for children's opportunities for physical activity e.g.

duration and frequency of PE, in – and outdoor education, duration and frequencies of recess. Every day and hour at school was therefore considered valuable in the analysis of physical activity. In study II a one-way ANOVA showed no significant differences between numbers of measured days (1–5) and mean school minutes in MVPA ( $p > 0.05$ ) thus all pupils with at least one day of data were included in the analysis. Further, in study I the pupils' free-living PA and PE in- and outdoors during school time were measured and pupils with PA data of at least a 120-minute period with at least one break were included in the analysis.

Data was downloaded in 10 second epochs and the sum of counts in each epoch categorized into LPA, MPA and VPA, using Evensons limits, (cut-points set to  $<17 \text{ counts} \times 10\text{s}^{-1}$  for sedentary,  $17 - 382 \text{ counts} \times 10\text{s}^{-1}$  for LPA,  $383 - 682 \text{ counts} \times 10\text{s}^{-1}$  for MPA and  $>682 \text{ counts} \times 10\text{s}^{-1}$  for VPA) (109, 110). Due to the intermittent pattern of children's physical activity 10s epochs were preferred (111). The consequences of using 10s epoch instead of 15s (cut-off points by Evenson et al. 2008) is reported to show a 2.95 % higher value for time in MVPA in eighth graders (33).

Different outcome variables of PA and different use of accelerometer axis in the analysis are presented in table 6. In study I and IV only vertical axis (VA) data was used which has been reported to be more valid when using the cut-off points by Evenson et al. 2008 (112). In both studies the total amount of accelerometer counts (TAC) generated in the different PA levels were used. TAC corresponds to variations in PA intensity above the specific threshold and compared to minutes in different PA intensity levels, TAC has been reported to show a slightly higher association with cardio-metabolic risk factors (113).

In study II data from all three accelerometer axis (vertical-*v*, horizontal-*h*, transversal-*t*) were converted into vector magnitude (VM) data by the formula  $VM = \sqrt{(v^2 + h^2 + t^2)}$ . VM-data was used to get as much PA data as possible in the analysis of environmental impact upon pupils' PA behavior. As valid cut-off points for MVPA when using VM-data with Actigraph GT3X+ did not exist in 2012 the validated and recommended cut-off points for VA-data by Evenson et al. 2008 were applied.

Table 6. Outcome (dependent) variables of PA and different use of accelerometer axis in the analysis.

Studies	Vertical axis data (VA-data)	Vector magnitude data (VM-data)
Study I	Counts per minutes (CPM) Total accelerometer counts (TAC) in different intensities (LPA, MPA, VPA) in- and outdoors.	
Study II		Total minutes spent in MVPA Percent of outdoor time spent in MVPA
Study IV	Total accelerometer counts (TAC) in MVPA in different play settings	

### **3.9 ASSESSMENT OF UVR**

For assessment of individual exposure to UVR, calibrated polysulphone film (ps-film) dosimeter badges were used (114, 115). The badge was pinned to the top of the right shoulder in the morning and taken off as the child left the school premises. Each pupil had the same dosimeter throughout the week. Due to the sampling epochs for the global UVR of 5 minutes with the Davis Instrument (see below), at least 5 minutes of outdoor data were required for analysis.

The dosimeters were purchased from the University of Manchester, School of Earth, Atmospheric and Environmental Sciences, UK, and returned and analyzed there after exposure. The absorbance of ps-film at 330 nm is measured before and after exposure and the difference entered into a polynomial function empirically formulated to give approximate results expressed as erythemal UV-exposures weighted according to CIE's erythema reference action spectrum (114). Polysulphone film dosimeters are proven to be reliable tools to measure personal UV-exposures (114, 116). For diurnal measurement of global UVR, three of the same ps-film dosimeters as worn by the children were mounted on high buildings or structures with free horizon close to the schools, and changed each night to obtain daily available exposures on a horizontal surface. To compute available global UV-exposure at 5-minute epochs a UV-index monitoring instrument (and computer software) from Davis Instruments, USA CA (Weather link 5.8.2) was used. The instrument had been factory calibrated to record UV index values, but was in this study used for relative measurement of UVR. The sensor of the instrument was taped down by the roof dosimeters. Diurnal distributions of readings, integrated and normalized to an average of the three roof-dosimeters were used to assess global UV-exposures during the children's periods of outdoor stay each particular day. Relative UVR (UVR%) was then calculated by dividing individually measured erythemal UVR values by the available global UVR values during each pupil's outdoor stay.

### **3.10 STATISTICAL ANALYSES**

Data was analyzed using the IBM SPSS statistics for Windows (22) and SAS for Windows software packages (version 9.4, SAS Institute Inc., Cary, NC, USA). Accelerometer data was processed using Acti Life 6.0 (Actigraph) and Microsoft Excel 2010 (Microsoft Corporation, Redmond, WA, USA). The statistical significance level was set to  $\leq 0.05$ . For descriptive statistics frequencies, mean, standard deviation, median and 5<sup>th</sup>-, 25<sup>th</sup>-, 75<sup>th</sup>- and 95<sup>th</sup>-percentiles were analyzed. The strength of correlation was interpreted using the Landis and Koch criteria according to Cohen's kappa value (117).

An overview of which outdoor environment predictors (independent variables) and outcome variables (dependent variables) were analyzed in the four studies is displayed in Table 7.

Table 7. Overview of measured environmental predictors (independent) and outcome (dependent) variables in the different studies.

STUDY	Environmental predictors	MVPA time (VM-data)	MVPA counts (VA-data)	UVR (J/m2)
I	Weather (index)		X	
	Temperature (day max)		X	
	Indoor vs. Outdoor		X	
	Free mobility vs. PE		X	
	Seasons		X	
II	Weather (index)	X		
	Temperature (day max)	X		
	Schoolyard area (m2)	X		
	Used play area (m2/child)	X		
	Ball play area (m2)	X		
	Green area (m2)	X		
	Outdoor education	X		
	Seasons	X		
III	Weather (index)			X
	Free sky view factor (%)			X
	Schools			X
	Seasons			X
IV	Weather (index)		X	X
	Temperature (day max)		X	X
	Play setting		X	X
	Free Sky view factor (%)		X	X
	Seasons		X	X

The following analytical statistic methods were applied:

STUDY I: Logistic regression – linear model, generalized estimating equation in GENMOD procedure (to evaluate how MVPA in terms of free mobility and PE is affected by the factors of indoor and outdoor school time, gender, weather, grades, weekdays, and seasons during stay at the school premises).

STUDY II: One way ANOVA test (analyzing differences in PA between days), independent t-test (differences in PA means between groups), paired t-test (differences between seasons and outdoor PA), intra-class coefficient (analyzing impact of school yard area upon PA), bivariate test using Spearman's rho and Pearson's correlation coefficient (identifying influence of confounders upon PA), linear mixed model repeated measurements - logistic regression (clustering measures of grade, school and gender within subjects, along seasons) were applied.



STUDY III: Interclass correlation coefficients were calculated to estimate the influence of environmental factors, such as weather and temperature, upon erythematous UV exposure during outdoor stay. A repeated measure ANOVA post hoc Bonferroni test was conducted to analyze differences in mean UVR exposures, outdoor times and SVF% of different seasons, schools, grades and gender. For bivariate analyses of confounders' association, Pearson's correlation coefficients were applied.

STUDY IV: Play settings (PS) set as an independent variable together with gender, grade and seasons, a one-way ANOVA test to evaluate the significant impacts of PS upon physical activity and exposure to UVR in different seasons, grades and gender. A Bonferroni post hoc test for any statistically significant differences for the PS variable. For confounder control of PA, bivariate analysis was carried out from diary records (medication, feeling well/unwell, PA outside school), none of them being significantly related to MVPA or UVR exposure.

## 4 RESULTS

### 4.1 PUPILS' PHYSICAL ACTIVITY (STUDIES I, II)

Throughout the seasons and during all days the pupils engaged in activities that enabled measurement by accelerometer, except for one 40-minute swimming lesson for each one of the 2<sup>nd</sup> graders at Art Grass 1 and City 3 in September, and at The Hill 4 in May. Mean wear time for all pupils and seasons was 4.5 (+0.7) days with a daily mean wear time of 345 ±43 minutes (270 ±46 indoors and 74 ±43 outdoors). Mean wear time for all pupils and seasons during 39 studied physical education lessons was 49 ±1.3 minutes (46 ±12 indoors and 56 ±24 outdoors).

#### 4.1.1 Time spent in MVPA (Study I, II)

There was a significant decline by age (years) in minutes spent in MVPA ( $p<0.001$ ) for both VA- data and VM- data (Fig. 8).

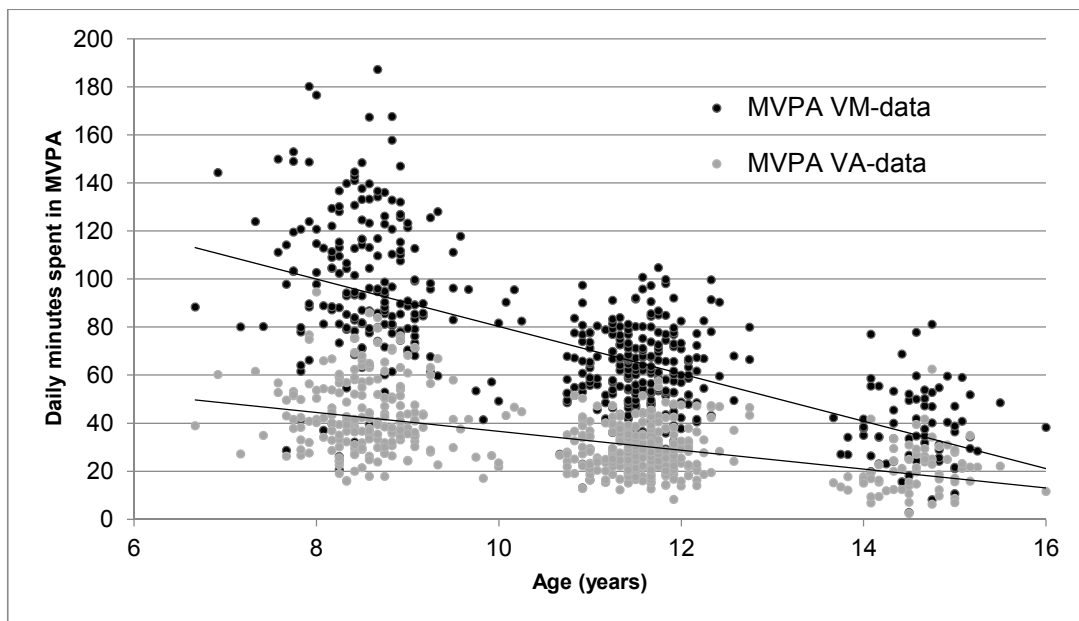


Figure 8. The association between age and daily minutes spent in MVPA at school in Swedish pupils, 2012-2013.

Time in MVPA calculated by VM accelerometer data (Study II) was significantly higher than time in MVPA calculated by VA accelerometer data (Study I, IV) when using the same cut points (110) (Fig. 8).

In terms of time spent in daily MVPA (both VA- and VM-data) and total daily counts in MVPA (VA-data) the 2<sup>nd</sup> graders were more physically active at school during all seasons compared to the older pupils. The least active during all seasons were the 8<sup>th</sup> graders. The

differences between VA and VM-data decline significantly by age (Fig. 8).

During the school day, and in terms of VA, 21% of the 2<sup>nd</sup> grader, 3% of the 5<sup>th</sup> graders and 2.5% of the 8<sup>th</sup> graders obtained the recommended levels of PA during the school year. Total average time spent in MVPA (VA-data) during the school day was  $33.7 \pm 20.1$  minutes (2<sup>nd</sup> graders =  $43.8 \pm 21.3$  min, 5<sup>th</sup> graders =  $29.0 \pm 14.4$  min, 8<sup>th</sup> graders =  $19.4 \pm 17.7$  min). The decline in outdoor stay and MVPA outdoors by increasing age applied to both genders. Boys spent significantly more time in MVPA than girls did, both outdoors and indoors. These differences remained after controlling for season, weather conditions and day of week. Further, outdoor time spent in MVPA increased by time at school as well as in September and May vs. March, and at the beginning of the week. Conversely, indoor MVPA declined as outdoor time increased during May. The 2<sup>nd</sup> graders accumulated  $28.6 (\pm 18.4)$  minutes in MVPA (VA-data) per day outdoors i.e. more than the 5<sup>th</sup> graders who obtained  $18.2 (\pm 13.3)$  minutes, and the 8<sup>th</sup> graders who spent  $6.5 (\pm 10.9)$  minutes in MVPA outdoors. Also, the 2<sup>nd</sup> graders accumulated more MVPA indoors than did their older peers.

#### 4.1.2 Accelerometer counts in different PA intensities (Studies I, IV)

During the academic year, pupils generated in average 50% of their total accelerometer counts outdoors. Outdoor time represented 25% of the entire stay at school. Total outdoor counts declined by age and were way out higher in boys than in girls. The difference between total PA counts generated indoors vs. outdoors shrank by age and was close to identical among 8<sup>th</sup> graders. Overall, outdoor free-living PA generated the highest mean accelerometer counts for both MPA and VPA, which applied to both genders except for boys in the 8<sup>th</sup> grade who generated more counts during PE outdoors compared to free-living PA outdoors (Table 7).

Table 7. Mean daily total accelerometer counts in different PA levels indoors and outdoors during time spent in free-living PA and PE (LPA, MPA, VPA) in different grades and gender, Sweden 2012-2013.

		Girls				Boys			
		Indoors		Outdoors		Indoors		Outdoors	
		Free-PA Mean	PE Mean	Free-PA Mean	PE Mean	Free-PA Mean	PE Mean	Free-PA Mean	PE Mean
2nd grade	Total counts	97483	20783	181698	42662	128032	21596	175295	49849
	LPA counts	49451	17124	42877	14519	59927	14612	49390	17757
	MPA counts	24112	15491	45339	19711	35030	13757	56230	27453
	VPA counts	23299	22410	93750	31103	32942	27692	69642	36667
5th grade	Total counts	74854	26576	98469	57697	91857	28553	112912	62910
	LPA counts	39855	13789	23227	17370	43228	14715	25698	18551
	MPA counts	17938	15341	27564	19520	23202	13817	34757	22466
	VPA counts	16072	36132	50562	31897	24438	31663	54539	42180
8th grade	Total counts	64466	21110	34219	49359	105309	18150	34067	88247
	LPA counts	31647	18760	8411	10055	41566	15377	10425	10842
	MPA counts	21212	17542	17770	20021	29785	21706	14867	18414
	VPA counts	11662	17221	12802	56548	33415	27742	11792	64973

## 4.2 PUPILS' ERYTHEMAL UVR EXPOSURE (STUDY III)

Outdoor time and UVR exposure was highly correlated during all seasons in all grades (Table 8). Available weekly ambient daily erythemal UVR (readings from the roof dosimeters) during the pupils' outdoor stays during school time varied between 27–540 J/m<sup>2</sup> (September), 13–220 J/m<sup>2</sup> (March) and 41–620 J/m<sup>2</sup> (May). Mean daily variations of individual exposures to erythemal UVR (readings from the shoulder-mounted dosimeters), were 6–212 J/m<sup>2</sup> (September), 4–75 J/m<sup>2</sup> (March) and 14–304 J/m<sup>2</sup> (May). Mean UVR exposures declined by age, and during all seasons boys among 2<sup>nd</sup> and 5<sup>th</sup> graders were more exposed than girls (Table 8). Mean relative UVR exposures were 34.4 % ± 12.3 (September), 31 % ± 11.5 (March) and 38.6% ± 12.8 (May).

The 2<sup>nd</sup> graders were more outdoors and more exposed to erythemal UVR than any of their older peers which applies to all seasons (Table 8). In May most of the 2<sup>nd</sup> graders passed the threshold limit for hazardous UVR exposure, meaning the calculated exposure range at the studied sites, according to guidelines for avoiding acute effects from UVR during one day as formulated by the International Commission on Non-Ionizing Radiation Protection (87). In September and March all pupils' exposures were suberythemal, i.e. <1MED (for skin type I), i.e. below the recommended safety exposure level of international guidelines to avoid acute effects (87, 88) in this study transformed into erythemal UV (120-140 J/m<sup>2</sup>).

The results also showed that almost all of the 2<sup>nd</sup> graders (98.5%) and most of the 5<sup>th</sup> graders (78.7%) may potentially have been sufficiently exposed for vitamin D acquisition (one standard vitamin D dose, SDD) in May during outdoor stay, which applies only to a few 2<sup>nd</sup> graders at City 3 and Hill 4 in March.

Table 8. Mean daily UVR exposures (J/m<sup>2</sup>), relative UVR (%) and time (minutes) spent outdoors in different seasons, grades and gender, Sweden 2012-2013.

			Daily UVR exposure (J/m <sup>2</sup> )		Relative UVR (%)		Time out	
			Mean	SD	Mean	SD	Mean	SD
2nd grade	September	Girls	68.3	±28.7	29.2	±9.6	110.1	±38.0
		Boys	95.2	±50.5	35.7	±13.2	116.4	±40.3
	March	Girls	37.6	±14.9	31.4	±9.5	90.9	±25.9
		Boys	41.6	±16.3	33.6	±9.2	79.5	±32.7
	May	Girls	126.1	±47.5	34.8	±10.9	120.4	±30.0
		Boys	172.2	±64.8	43.5	±10.7	137.9	±28.8
5th grade	September	Girls	54.1	±18.3	31.7	±10.0	75.1	±23.4
		Boys	65.7	±20.3	38.3	±10.8	77.9	±24.3
	March	Girls	30.3	±10.4	26.2	±8.6	62.3	±39.7
		Boys	34.2	±7.4	30.7	±10.8	53.2	±33.7
	May	Girls	77.1	±26.9	33.9	±11.8	74.7	±31.4
		Boys	84.1	±30.7	36.3	±12.1	74.8	±33.8
8th grade	September	Girls	27.0	±22.2	31.5	±16.8	34.2	±17.8
		Boys	27.6	±19.7	38.5	±16.8	51.3	±27.1
	March	Girls	7.4	±3.1	33.1	±12.0	13.3	±6.1
		Boys	10.7	±5.2	36.7	±21.3	14.4	±12.1
	May	Girls	53.9	±38.1	46.6	±16.4	45.1	±28.7
		Boys	50.9	±25.8	51.3	±11.6	31.9	±29.6

## 4.3 ENVIRONMENTAL IMPACT UPON PUPILS MVPA AND UVR EXPOSURE

### 4.3.1 Environmental impact upon pupils' MVPA (STUDIES I, II, IV)

Analyses of study II (VM-data) were rerun along VA-data and then compared to the results with VM-data. Study II revealed a positive correlation between minutes spent outdoors and minutes spent in MVPA ( $r = 0.711$ ,  $p < 0.001$ ). There was an increased correlation when using VA data ( $r=0.817$ ,  $p<0.001$ ). Different p-values between VM and VA-data regarding season and school impact upon the pupils's PA outdoors were observed, (Table 9).

Table 9. Predictors for physical activity level during school outdoor stay (% of PA minutes in MVPA) when using different accelerometer axis in the analysis.

Mixed model, Typ III tests of fixed effects, repeated for seasons, F-values (Standard error)		% in MVPA VA-data			% in MVPA VM-data		
Variable	(compared variable)	Estimate	Std. Error	p-value*	Estimate	Std. Error	p-value
	Intercept	<b>30,76</b>	2,07	<0.001	<b>46,43</b>	1,62	<0.001
Season	March (September)	-5,64	1,13	<0.001	-10,99	1,48	<0.001
	May (September)	-0,16	0,89	0,855	-4,55	1,15	<0.001
School	Hill 4 (City 3)	4,84	1,55	0,002	1,82	1,72	0.292
	Forest 2 (City 3)	5,54	1,52	<0.001	10,76	1,62	<0.001
	Art Grass 1 (City 3)	8,61	1,62	<0.001	12,94	1,78	<0.001
Grade	5 <sup>th</sup> grade (2 <sup>nd</sup> grade)	-7,50	1,72	<0.001	-6,17	1,32	<0.001
	8 <sup>th</sup> grade (2 <sup>nd</sup> grade)	-8,51	1,78	<0.001	-4,97	1,93	0.011
Gender	Boys (Girls)	4,48	1,11	<0.001	7,35	1,24	<0.001

\* significant differences  $p<0.05$

#### 4.3.1.1 Weather and temperature

The weather in March and May was mostly sunny compared to more cloudiness and one day with heavy rain in September. Results from study I showed that MVPA counts outdoors dropped significantly as the weather became increasingly inclement throughout all grades. Day maximal temperatures during September and May significantly increased MVPA counts outdoors. This did not apply in March in any of the locations, in spite of mostly sunny weather.

#### 4.3.1.2 Schoolyard area

Study II investigated the impact of schoolyard area at compulsory schools upon pupils' patterns of physical activity considering season, age and gender. Results showed that the area used for play expanded as time spent in MVPA increased in 2<sup>nd</sup> and 5<sup>th</sup> graders. This applied

to all pupils except girls of the 2<sup>nd</sup> grade whose MVPA instead decreased. On the other hand, in both September and March green play areas significantly increased time spent in MVPA in this very group. Among 8<sup>th</sup> graders no significant impact of any of the environmental factors on time spent in MVPA was observed.

#### 4.3.1.3 Play settings and free sky view

Study IV showed that 2<sup>nd</sup> and 5<sup>th</sup> graders, boys and girls obtained most MVPA counts at sport fields compared to the other play settings (Figure 9). Paved surfaces generated the lowest MVPA levels during the year. Girls in the 2<sup>nd</sup> and 5<sup>th</sup> grades obtained more minutes in MVPA vs. boys on paved surfaces and in green settings, on the other hand did boys get more counts in MVPA vs. girls in the same play settings (Figure 9).

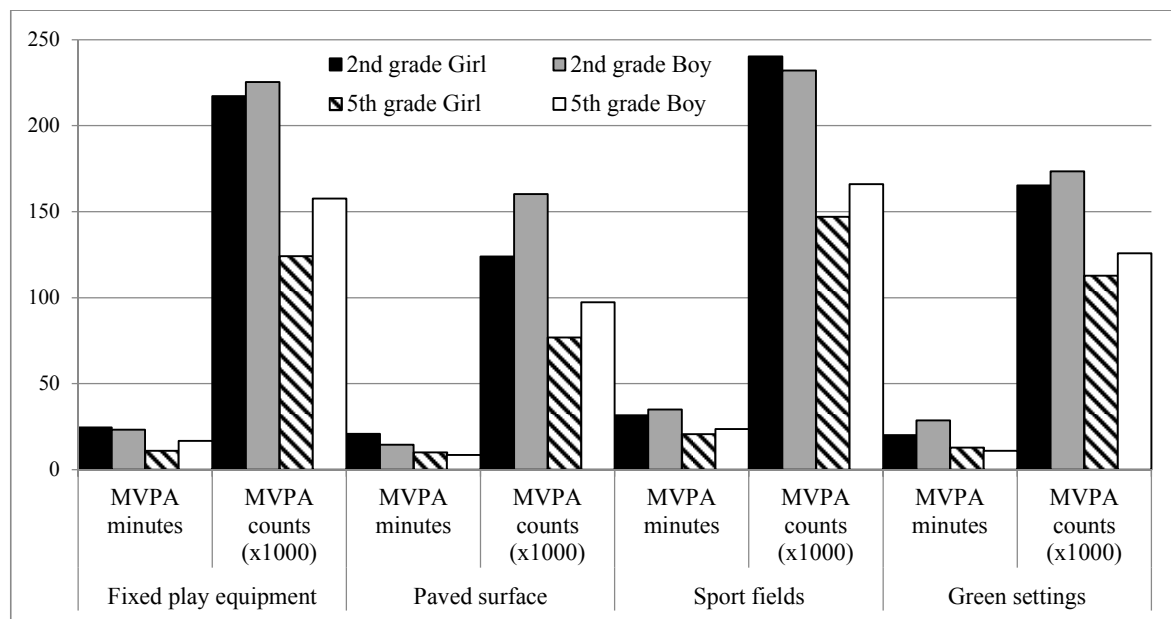


Figure 9. MVPA levels (VA-data, minutes and counts) spent in different play settings during one academic year by grade and gender, Sweden 2012 and 2013.

In September sport fields generated higher mean MVPA counts vs. fixed play equipment and paved surfaces ( $p < 0.05$ ). In March sport fields generated higher MVPA level vs. all other play settings ( $p < 0.01$ ) and in May vs. play at paved surfaces and green settings ( $p < 0.01$ ).

Table 10 shows predictors of the participants TAC in MVPA during school outdoor stay. TAC in MVPA was significantly higher during May vs. September and March, 2<sup>nd</sup> graders generated more than 5<sup>th</sup> graders, boys more than girls and sport fields were the strongest predictor for MVPA compared to other play settings.

Table 10. Predictors for PA level during school outdoor stay (MVPA counts, VA-data).

Mixed model, Type II tests of fixed effects, repeated for seasons, F-value, standard error		95% CI					
Variable	(compared variable)	Intercept:	Estimate	SE	t-value	p-value*	Lower Bound Upper Bound
Seasons	September (May)		150 728	10475	14.4	<0.001	130 111 171 344
	March (May)		-20 504	8253	-2.5	0.014	-36 825 -4 183
Grade	2nd (5th)		-36 972	8327	-4.4	<0.001	-53 413 -20 531
	Girls (boys)		63 294	7459	8.5	<0.001	48 542 78 045
Play setting	Fixed play equipment (Green setting)		-24 186	7498	-3.2	0.002	-39 007 -9 364
	Paved surface (Green setting)		20 771	7726	2.7	0.008	5 550 35 993
	Sport field (Green setting)		-14 888	8230	-1.8	0.072	-31 130 1 355
			31 112	8180	3.8	<0.001	15 019 47 206

\* significant differences  $p < 0.05$

In 5<sup>th</sup> graders a lower sky view factor was correlated to a decline in MVPA counts in March ( $p < 0.001$ ), and an increasing sky view factor correlated to increasing MVPA in May ( $p < 0.036$ ).

### 4.3.2 Environmental impact upon erythematous UVR exposure (Study III, IV)

#### 4.3.2.1 Sky view factor

The mean fraction of free sky view from all positions differed significantly between schools as did relative UVR exposures between schools and grades, with Forest 2 having 15–20% less free sky view than the other schools (Table 11).

Table 11. Descriptive data of school specific environmental factors and individual exposures in different schools and seasons.

School environment		Art Grass 1	Forest 2	City 3	Hill 4
Sept/March/May	Solar Zenith Angle	53.3/60.8/39.7	54.7/62.2/40.1	55.1/62.7/40.4	55.1/62.7/40.4
	UV index (weekly mean noon-time)††	2.0/1.3/2.7	1.8/1.3/3.6	1.4/1.3/3.5	1.4/1.3/3.5
	UV index (Max by clear sky)††	4.0/2.3/6.9	4.3/3.1/6.7	3.3/2.4/6.0	3.3/2.4/6.0
	Maximal available UVR (day mean)	265/76/258	218/111/233	126/115/290	186/147/383
	Sky view fraction (% free sky)	76/89/80	58/58/68	77/77/75	73/77/80

††Readings from the Davis UV monitor

In September, the positive correlation between free sky view and relative UVR exposure was high in all grades and moderate in March in grades 2 and 5, and unrelated in grade 8. In May, the correlation was fairly positive in grade 2 and moderately negative in grades 5 and 8. Figure 10 shows the correlation between free sky view and relative UVR exposure during all seasons.

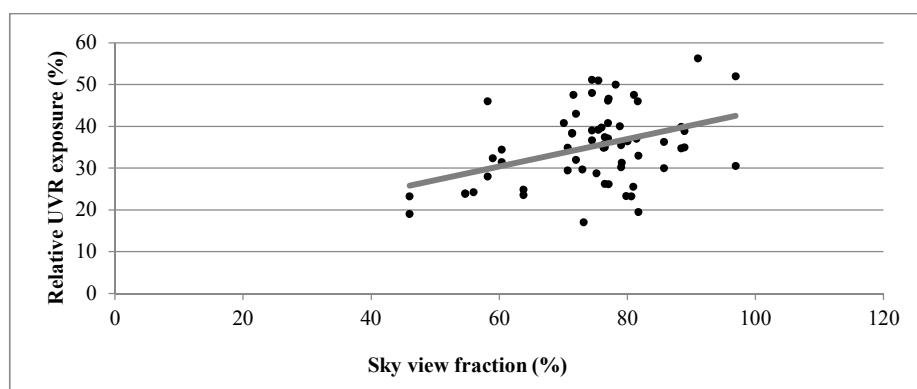


Figure 10. Correlation between the free sky view and relative UVR exposure during three seasons in Sweden 2012-2013.

#### 4.3.2.2 Play settings

Apart from season, the sport field setting appeared to be the strongest predictor for increased UVR, where the pupils also obtained the highest UVR exposures during May vs. all other play settings (Table 12).

Table 12. Predictors for UV level during school outdoor stay (daily UVR exposure, J/m<sup>2</sup>), Sweden 2012-2013.

							95% CI	
Mixed model, Type II tests of fixed effects, repeated for seasons, F-value, standard error			Estimate	SE	t-value	p-value*	Lower Bound	Upper Bound
Variable	(Compared variable)	Intercept:	101.1	4.8	21.0	<0.001	91.6	110.6
Seasons	September (May)		-41.1	4.7	-8.7	<0.001	-50.5	-31.8
	March (May)		-71.0	4.1	-17.1	<0.001	-79.2	-62.8
Grade	2nd (5th)		5.6	1.9	2.9	<0.004	1.8	9.5
Gender	Girls (boys)		-4.9	1.9	-2.5	0.012	-8.8	-1.1
Play setting	Fixed play equipment (Green setting)		8.4	2.8	3.0	0.003	2.9	13.9
	Paved surface (Green setting)		6.3	2.1	3.0	0.004	2.1	10.5
	Sport field (Green setting)		14.9	2.6	5.6	<0.001	9.6	20.1

\* significant differences  $p < 0.05$

Table 13 shows mean daily UVR exposures (J/m<sup>2</sup>) and relative UVR exposure (%) in different play settings at different seasons. In September and March PA at sport fields generated higher UVR exposure vs. fixed play equipment and green settings. During March UVR exposure at green settings was negligible and lower than anywhere else (Table 13).

Table 13. Daily mean UVR exposure (J/m<sup>2</sup> and % of available UVR) in different play settings and seasons. Sweden 2012-

		Fixed play equipment		Paved surface		Sport fields		Green settings	
Season	Daily mean UVR exposure	Mean	SD	Mean	SD	Mean	SD	Mean	SD
September	UVR exposure (J/m <sup>2</sup> )	58,5	30,5	76,5	34,6	80,5	38,2	62,3	17,4
	Relative UVR exposure (%)	30,7	11,4	35,1	11,6	37,6	9,9	31,9	12,5
March	UVR exposure (J/m <sup>2</sup> )	41,7	15	38,3	15,1	39	12,1	29,5	6,7
	Relative UVR exposure (%)	30	10,6	36,9	9,5	28,3	8,0	24,7	6,2
May	UVR exposure (J/m <sup>2</sup> )	94,6	41,4	90,3	15,4	140,8	64,1	72,3	26,9
	Relative UVR exposure (%)	32,6	9,9	49,2	9,1	39,8	12,0	33,1	11,1



## 5 DISCUSSION

### 5.1 PHYSICAL ACTIVITY

#### 5.1.1 PA at different ages

Studies I (VA-data) and II (VM-data) revealed a steep decline in PA by age. At school, the 2<sup>nd</sup> graders' time in MVPA was 50% longer than that of the 8<sup>th</sup> graders. This decline of MVPA by age has been reported in cross-sectional studies (57, 58, 118). Sherar et al. conclude, based on whole day data, that children's PA decreases between 8 and 13 years, both by chronological and biological age (119). They also conclude that further studies are needed to explain the decline in PA from childhood to adolescence. Part in the decline of the overall PA by age might be explained by increasingly demanding schedules in the upper grades, displayed by about 20% longer indoor time in 8<sup>th</sup> graders vs. 2<sup>nd</sup> graders. Among 8<sup>th</sup> graders PE outdoors contributed with 82% of total MVPA generated at school, whereas free-living MVPA was low, especially in May.

The use of different cut points has made it difficult both to compare studies and to determine the proportion of children attaining the recommended daily PA level (46). It has been shown that the proportion of children (age  $\leq 12$  years) who meet the daily MVPA recommendations ranged from 36–87% with a cut-off point of approximately 2000 counts per minute (analyzed with VA, data) (46). Using VM-data for the analysis (study II) almost all 2<sup>nd</sup> graders reached the recommended 60 minutes in MVPA during school time, but using VA-data (study I) only about 21% of the 2<sup>nd</sup> graders did so. Irrespective data used for analysis (VM or VA) only very few of the 8<sup>th</sup> graders obtained optimal levels of daily PA which makes the post-school time important in promoting PA in older children and youth. Some of the pupils may compensate lacking PA at school with PA after school. A systematic review (120) showed that 15 of 28 studies provided evidence of compensation, 13 did not (120). Dale et al. (2013) showed no compensation of PA after sedentary school days in 3<sup>rd</sup> and 4<sup>th</sup> grade elementary school children. On the other hand, the children were more active after active school days (121). Promoting PA during school time thus seems to be an adequate approach.

Questionnaire and diary data showed that most of the 5<sup>th</sup> and 8<sup>th</sup> graders participated in different after school activities, though the quantity and quality of these activities in terms of intensity, frequency and duration was not assessed.

##### 5.1.1.1 Reactiveness

It is difficult to know what really affects variations in children's physical activity between school days during one week. This motivated us not to exclude any days in analysis due to possible reactivity. Davis et al. reported no reactivity in children's PA (122). However, a

higher activity on Mondays vs. Fridays could be explained by the fact that pupils were well rested after the weekend and tired after a week at school. As stated above the scheduled time is crucial for children's opportunities for physical activity e.g. PE duration and frequencies, indoor – outdoor education, recess duration and frequencies. Thus every day and hour at school is unique and therefore assessed as important in the analysis. About 30% of the pupils in our study had physical education on Mondays compared to 15% on Fridays.

### **5.1.2 Environmental impact upon PA**

#### *5.1.2.1 Indoor and outdoor PA*

A commonly reported environmental impact on school children's PA is the amount of time spent outdoors (61, 123). In study II (VM-data) the results too showed a strong positive correlation between outdoor time and total amount of PA during schooldays in all pupils irrespective of age. Further, study I (VA-data) showed that free mobility outdoors during the school day was the greatest provider of daily PA not only in comparison to indoor stay, but also in comparison to PE in 7-11 year-old pupils during all seasons, both in terms of mean total accelerometer counts and CPM. It has also been reported that 6-11 years old pupils' PA levels are higher on the schoolyard compared to the average over the whole day (11). Indoor PA was characterized by extended bouts of LPA and was only one fifth of the intensity (CPM) in comparison to that of outdoor PA. On the other hand PA intensity (CPM) during indoor PE was in line with outdoor PE making the PE time important during winter and inclement weather when free mobility during recess tend to take place indoors and with less intensity.

#### *5.1.2.2 Seasonal differences in pupils' PA*

Seasonal differences regarding MVPA outdoors were observed in all studies involving PA (I, II and IV). Pupils of all grades spent most minutes in MVPA during fall and late spring, compared to late winter. Those findings correspond with reported results showing that children are less active in winter than during other seasons, generally in areas with cold and long winters (124-126). However, significant seasonal differences were observed only among 2<sup>nd</sup> and 5<sup>th</sup> graders and during all seasons 2<sup>nd</sup> graders obtained more MVPA than the 5<sup>th</sup> graders. Between late winter and late spring, boys in the 2<sup>nd</sup> grade represented the largest seasonal shifts. The reason for this is unknown.

#### *5.1.2.3 Impact of different playground areas upon PA*

Vegetation and woodland have previously been shown to increase physical activity among older preschoolers (53) and among school children (127), particularly among girls. This is concordant with our observations, showing that girls at school no.2, with an environment of vast woodland and green settings spent significantly more outdoor time in MVPA than did

girls at the other schools. Open spaces seem to contribute to maintaining MVPA among pupils, as they grow older. Among girls, woodland seems to fulfill that function as well. In accordance with previous studies, we too observed significant and positive correlations between time spent in MVPA during outdoor stay and temperature in 2<sup>nd</sup> and 5<sup>th</sup> graders (128, 129).

Attention needs to be paid considering the location and design of play spaces and equipment at schools that allow pupils of all ages to use the whole school ground (74). For instance, the 2<sup>nd</sup> and 5<sup>th</sup> graders had play settings designed for their age or settings otherwise suited for free-living physical activity by their classrooms, which the classrooms of the eighth graders did not have.

#### *5.1.2.4 Impact of different play settings upon PA*

The results of study IV (VA-data) suggest that playing soccer, floor ball or basketball on vast open sport fields with largely free sky view appeared to increase both PA levels and UVR exposures and for part of the boys yielded the largest amount MVPA counts and highest mean UVR exposures vs. all the other play settings. The higher level of MVPA at sport fields matches the results from systematic reviews of PA during school recess showing that school facilities (like sledding hills and soccer fields), play-ground markings and unfixed equipment (such as ball per child ratio) have a potential to increase PA levels during recess (51, 73). It is important to take into account that fixed play equipment like climbing frames, slides and swings could have major potential improvement of children's motor skills that accelerometers do not capture. Improved motor skills in turn, have been shown to be important for children's self-esteem (2). Our younger pupils were observed to often use open paved surfaces for ballgames with space and surface for the ball to bounce. This kind of PA did not show high levels of PA but could have a potential for other health effects such as the improvement of motor skills. Further, a previous Swedish study points to the important role of paved open spaces for PA as children tend to run a lot in many of the traditional schoolyard games including elements of hide and seek and chasing (74). Our conflicting results possibly depend on the fact that children with woodland and artificial turf at hand get more inclined to use these rather than the open paved areas (74).

For improved understanding of the synergetic effects of schoolyard play on factors relevant to health the limitations of this study need to be acknowledged. For instance the physical environment was categorized into play settings (study IV) which in analysis were defined as separate factors, without considering the overall layout and interaction of the different settings (130). Environmental dimensions guiding the design of play settings for preschoolers point to important configurations of environmental characteristics dependent on the overall size and layout of vegetation and play equipment in open spaces (130).

## **5.2 UVR EXPOSURE**

### **5.2.1 Suberythral UVR exposure at Swedish primary school**

The results of study III showed that in September and March UVR exposures during school time were suberythral ( $<1\text{MED}$ ) for skin type I, according to the recommended safety exposure level of international guidelines to avoid acute effects (87, 88), i.e. in this study UVR  $120\text{-}140\text{ J/m}^2$ . Further, the results showed that in May the recommended safety exposure level was exceeded by most 2<sup>nd</sup> graders which should be taken into consideration when planning for healthy schools.

Time spent outdoors during the school day affected erythral UVR exposure in different ways depending on age. In May, younger pupils (7-11 years old) spent 28% of the day outdoors and ran a higher risk of exceeding the UV threshold limits compared to older pupils whose mean outdoor time during the risky season was only about 10% of their total time at school. From the viewpoint of erythral UVR the older pupils could probably have spent more time outdoors without risk of sunburn, at least in September and March. In May outdoor times were longest and mean daily UVR exposures highest in all grades. Among 8<sup>th</sup> graders at school no.2 high UVR exposures may be explained by outdoor PE taking place at the soccer field (SVF= 96%) which made up most of their time spent outside.

Optimal vitamin D level is under debate and studies have shown that in children and adolescents living in Nordic countries, pre-vitamin D3 levels may be below recommended levels (131, 132). UVR exposure is crucial for the initiation of vitamin D formation (133), and repeated exposures of one SED or less are clearly sufficient for vitamin D acquisition if the exposed skin area is large (134). Results in study III showed that most of the 2<sup>nd</sup> and the 5<sup>th</sup> graders may potentially have been sufficiently exposed for vitamin D formation gaining one standard vitamin D dose in May during outdoor stay. In March the 8<sup>th</sup> graders' UVR exposures were far below the levels for potential vitamin D formation. The pupils at school no. 2 displayed the lowest UVR exposures during all seasons, most likely due to the high range of green settings and the surrounding woodland with huge fir trees. This could have implications for potential vitamin D formation in fall and early spring.

In September and May some pupils though, both 2<sup>nd</sup> and 5<sup>th</sup> graders, reached the erythral UVR exposure zone ( $120\text{-}140\text{ J/m}^2$ ) corresponding to international UV-hazard guidelines for avoidance of acute effects.

### **5.2.2 Impact of outdoor environment upon UVR exposure**

#### *5.2.2.1 Impact of free sky view upon UVR exposure*

Previous studies focusing on how preschool children's physical activity depends on sun protective surroundings of the preschools have shown high relationships between relative

UVR exposure and free sky view and also between sun-protective surroundings and physical activity (16, 53). In study III too, a positive relationship between UVR exposure and free sky view was observed with the exception of 8<sup>th</sup> graders in March and a negative relationship for both 5<sup>th</sup> and 8<sup>th</sup> graders in May. Sources of error may have occurred, as some of these pupils were observed to sunbathe while the badges may have been underexposed. Or possibly the SVF-viewpoints were not optimally representative for those pupils' whereabouts. On those occasions some pupils may have worn or handled their garments in a way that the dosimeters were overexposed. On some occasions, the observers noticed that a garment with the dosimeter was dropped in the sun, and even though in most of these cases the observer intervened, yet in a few cases this may have occurred undetected. Yet, study III further indicates the association between sun protective surroundings, woodland, and physical activity for younger schoolchildren at primary school. Thus, a link seems confirmed between low UVR exposure due to sun-protective environments and increased physical activity. As previously mentioned, the largely free sky view on vast open sport fields not unexpectedly increased UVR exposure and for part of the boys yielded the highest mean UVR exposure vs. all the other play settings. Possibly, reflecting gravel on the soccer field at school no.3, where boys in the 2<sup>nd</sup> grade displayed the highest UVR exposures in May, could have contributed. Gravel surfaces have been reported to reflect as much as 25% of the UVR compared to grass with almost no reflection of UVR (99). In May grass on sport fields may lower the risk for hazardous UVR exposure as would extended recesses or scheduled PA in the mornings and – if applicable – late afternoons as well as reduced time out in the middle of the day between 11 am and 01 pm during the time of the academic year when the sun is high.

#### *5.2.2.2 Impact of outdoor education upon UVR exposure*

Outdoor lessons under open skies increase the risk of UVR-related skin lesions (melanocytic naevi) (100). However, prolonged outdoor lessons in May would be possible in an outdoor environment disposing of woodland and/or roofed over areas. In a study of 2011, erythema UVR exposure was very low among preschool children in North Carolina in March/April (Lat 36°N) in spite of midday outdoor stay, due to abundant vegetation (16). This gives an indication that suberythema UVR exposure is feasible, at least in young children. The younger pupils at school no.2 had one day of outdoor education during fieldwork in March and May and showed significantly lower UVR exposure vs. to the other schools investigated. In these cases, outdoor education took place in the woodland and the free sky view was significantly lower compared to the other schools in the study. However, if trees cut the sky views in March pupils may well pursue activities under open skies, which could possibly initiate some formation of vitamin D.

## **5.3 STRENGTHS AND LIMITATIONS**

### **5.3.1 Strengths**

It is proven hard to recall details in physical activity patterns (60, 126) and the strength of this thesis was the use of objective monitoring of outdoor time and intensity of PA - as well as objective measurement of UVR exposure. Further, comparing the Actilux readings to the recordings of outdoor times by direct observation made the data of clocked outdoor time more reliable. Further, data was collected within a maximum time span of three weeks for each season. Though important for reliability this does not seem to be frequently applied in seasonal studies of physical activity and UVR exposure, which may be explained by organizational difficulties. An important experience during fieldwork was the pupils' occasional lack of adherence to the schedule for lessons and recess times, which made direct observation necessary in order to obtain relevant and reliable data.

### **5.3.2 Limitations**

Weaknesses of the studies were firstly the limited sample of schools. However, between the choices of investigating a more extensive sample combined with increased risks of unreliable fieldwork (e.g. measurement by proxy) or reliable but resource-consuming data collection in a smaller sample our choice was motivated by the variation in the outdoor school settings. We drew the conclusion that thorough fieldwork, though in a small sample, would deliver more valuable and more generalizable data not least due to the variation of the outdoor school grounds. Secondly, the high dropout among 8<sup>th</sup> graders - possibly a consequence of unconsolidated identity protected by a high feeling of integrity - motivates caution in interpreting this particular data.

Further, it should be emphasized that exposures of the dosimeters worn on clothing were recorded, indicative of possible exposures of uncovered skin. Thus only the prerequisites for the pupils' exposures were investigated – not actual UV-doses obtained nor their health consequences. The terms “MED” and “SED” are exposures defined per unit area ( $\text{J/m}^2$ ) – but not “SDD”, as vitamin-D acquisition also depends on exposed skin area. Per definition, UV-doses depend on the amount of skin subjected to solar exposure and thus on clothing. Swedish children do not wear school uniforms and clothing may vary considerably with season, temperature and weather. Nor did we report data on clothing or exposed skin area. Actual vitamin-D status (blood serum levels) was not measured – nor was it estimated from food intake reports (which were not requested). However, in view of the fact that outdoor stay is increasingly advocated for reasons of outdoor education and health (135, 136) more suberythral outdoor stay could – at least in theory – contribute to the pupils' opportunities to acquire vitamin D.

## **5.4 FURTHER RESEARCH**

The further elaboration of distinct play settings as part of a toolbox for school ground development, as elaborated in this study, needs to be combined with study of the interactive effects in between the play settings, which also considers their location in the overall layout of the schoolyard and their relation to the surrounding landscape. We would suggest to further elaborate on how to add attributes from green settings to the other types of settings – including those of sport fields and fixed play equipment – without forgetting the paved spaces in proximity to entrances (74). Those tend to house many of the vigorous games typical for a schoolyard, and – provided they contain “nooks and crannies” are attractive to both girls and boys (137).

For further study, the following may be considered as well:

The exploration of more schools, grades and pupils for improved generalizability, including inner city schools with small or no schoolyards at all, and rural schools.

The use of GPS and time stamped action cameras on the pupils that would enable the tracking the whereabouts of each one of them on a continuous basis.

Employing time-stamped UVR measuring devices, which would make it possible to study the combined effect of PA and UVR exposure.

## 6 CONCLUSION

At elementary school

- More outdoor time at school during all seasons may increase MVPA in children aged 7-15 years, particularly as free-living outdoor recess seems to be the best contributor to MVPA, as least in lower grades, and outdoor PE in older pupils may be a key factor to increase MVPA during school time.
- Throughout all grades boys are more physically active than girls during school time, both during free-living PA and PE lessons. As woodland seems to trigger girls' PA such areas should be made available whenever possible. Green play areas with woodland as well as extended ball areas with art grass also seem to enhance MVPA in 2<sup>nd</sup> and 5<sup>th</sup> graders during outdoor stay.
- There is space for prolonged suberythema outdoor stay in September and March, e.g. by play in open areas during fall and early spring. The chance for more outdoor stay may therefore well be utilized, e.g. by outdoor sport activities which combine high levels of accelerometer counts in MVPA and safe UV exposure during that time of the year. The drop in MVPA and low UVR exposure in all pupils in March may be compensated by more of outdoor activities during sunny days, especially at high latitudes. This would also improve the opportunities for the skin to gradually adapt to the increasing intensity of erythemally effective solar UVR.
- The interaction between attributes of the physical environment and level of PA and UVR exposure in 2<sup>nd</sup> and 5<sup>th</sup> graders warrants access to sport fields due to the positive impact upon both MVPA and potentially sufficient suberythema UVR exposure for vitamin D production in September, as well as fixed play equipment and green areas with trees and shrubs in May protect from hazardous UV exposure and promote high levels of MVPA.
- In late spring UV protection is warranted, and with green settings being protective, areas of trees and shrubs should be made available which spur MVPA by arousing curiosity and inviting both girls and boys to exploration. Long outdoor exposures of the youngest pupils therefore warrant UVR-protective environment in May. Ultimately, this is an issue for scheduling of outdoor education and landscape architecture with expert knowledge of local climate and landscape features in many countries, not only in Sweden.



## 7 IMPLICATIONS

As a promoter of PA, school health policies should highlight outdoor recess as an important factor for sustained health. As recommended by the WHO, PE should be considered as an integrated part of creating health-promoting environments. In Sweden, the subject of PE includes theory and is not considered to be solely responsible for satisfying the need of school children's PA. It is possible that this approach needs to be revised. In our investigation, only the second graders obtained the recommended levels of PA during the school day as a mean, which none of the others did during any season in terms of mean values. Particularly, the 8<sup>th</sup> graders' low levels of PA are a reason for concern. To promote health, the school administrators should provide more opportunities for pupils to get the benefits of outdoor recess during the school day, especially for girls in the upper grades. Outdoor recess is even more important during winter, particularly when there is no scheduled outdoor PE. Additionally, the opportunities for both outdoor PE and theoretical outdoor education during all seasons (winter included) should be explored, as both may have the potential to trigger additional and initially unplanned mobility, which does not fall outside the frame of the lesson. In addition, the share of the pupils below the 75th percentile of PA needs to be considered. An expansion of outdoor education may serve to push them towards desirable and recommended levels of PA and sufficient suberythema UVR exposure for potential health effects. In recent years, schools have been established in Sweden without any access to the surrounding outdoor environment. Even though the implications for PA are discussed in this context, this trend needs to be carefully monitored where free-living PA outdoors during school time is concerned, due to its valuable contribution to maintaining high levels of MVPA and for sufficient suberythema UVR exposure.

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